PB82-108408

Oil Content in Produced Brine on Ten Louisiana Production Platforms

Crest Engineering, Inc.
Tulsa, OK

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Sep 81

U.S. Department of Commerce
National Technical Information Service
NTIS

EPA-600/2-81-209
September 1981
PB82-108408

OIL CONTENT IN PRODUCED BRINE ON TEN LOUISIANA PRODUCTION PLATFORMS

by

George F. Jackson and Eugene Hume
Crest Engineering, Inc.
Tulsa, Oklahoma 74101

and

Michael J. Wade
Texas Instruments, Inc.
Dallas, Texas 75165

and

Milton Kirsch
Rockwell International Corporation
Newbury Park, California 91320

Contract No. 68-03-2648

Project Officer

John S. Farlow
Oil & Hazardous Materials Spills Branch
Municipal Environmental Research Laboratory-Cincinnati
Edison, New Jersey 08837

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-81-209	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB82 108408
4. TITLE AND SUBTITLE Oil Content in Produced Brine on Ten Louisiana Production Platforms		5. REPORT DATE September 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) George F. Jackson, Eugene Hume, Michael J. Wade and Milton Kirsch		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Crest Engineering Inc. P.O. Box 1859 Tulsa, OK 74101		10. PROGRAM ELEMENT NO. 1NE823
		11. CONTRACT/GRANT NO. 68-03-2648
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

John S. Farlow, Project Officer (201-321-6631)

16. ABSTRACT

A survey of the oil content of brine effluents from offshore crude oil production platforms was conducted for the Oil and Hazardous Spills Branch of the Environmental Protection Agency. The objectives were to determine the amount of oil in the brine, and to determine the factors affecting brine oil content variability.

Ten-day surveys were conducted on ten platforms. The platforms selected represented a wide range of characteristics with respect to produced fluids, processing systems, and water treating systems. Each platform had a flotation unit for final oil separation before discharge.

Minimums of forty gravimetric and twenty infrared oil content tests were run on brine effluents of each platform. Oil content tests were also run at upstream points in the systems. Other brine tests run for correlation with effluent oil content included: soluble oil, oil drop-size distribution, suspended solids, surface tension, ionic analysis, pH, specific gravity, surface tension, boiling point distribution, and temperature.

Records were kept of operational factors including: water cuts, lift methods, pressures, chemical addition programs, and hydraulic loading of water treating units.

Test data and operational data were analyzed for correlation with effluent oil content data.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Oil Recovery Environmental Engineering Water Pollution Water Treatment Oils	Produced Water Treatment Unit Process Efficacy Chem: Analytical Methods Brine Oil Content Variability	

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) UNCLASSIFIED	21.
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

THIS DOCUMENT HAS BEEN REPRODUCED FROM THE BEST COPY FURNISHED US BY THE SPONSORING AGENCY. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problems.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report describes the results of a ten-day survey of the oil content of effluent brine (and of the factors that might affect the observed variability) on ten oil and gas production platforms off the coast of Louisiana. The project provided an extensive base of high quality data, which will be of interest to those concerned with oil/water separation problems relating to petroleum production.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

ABSTRACT

A survey of the oil content of brine effluents from offshore crude oil production platforms was conducted for the Oil and Hazardous Spills Branch of the Environmental Protection Agency. The objectives were to determine the amount of oil in the brine, and to determine the factors affecting brine oil content variability.

Ten-day surveys were conducted on ten platforms. The platforms selected represented a wide range of characteristics with respect to produced fluids, processing systems, and water treating systems. Each platform had a flotation unit for final oil separation before discharge.

Minimums of forty gravimetric and twenty infrared oil content tests were run on brine effluents of each platform. Oil content tests were also run at upstream points in the systems. Other brine tests run for correlation with effluent oil content included: soluble oil, oil drop-size distribution, suspended solids, surface tension, ionic analysis, pH, specific gravity, and temperature. Crude oil tests included specific gravity, surface tension, boiling point distribution, and temperature.

Records were kept of operational factors including: water cuts, lift methods, pressures, chemical addition programs, and hydraulic loading of water treating units.

Test data and operational data were analyzed for correlation with effluent oil content data.

This report was submitted in partial fulfillment of Contract No. 68-03-2648 by Rockwell International under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period February 1978 to August 1980, and work was completed as of August 1981.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

CONTENTS

Foreword ii
Abstract iv
Figures viii
Tables xv
Metric Conversion Factors xxv
Abbreviations and Symbols xxvi
Acknowledgements xxviii

1. Introduction 1
2. Summary 4
3. Conclusions 11
4. Recommendations 13
    Scope 13
    Background 13
    Specific Recommendations 14
5. Program Plan 15
    Objectives 15
    Background Information 15
    Technical Approach 15
    Analytical Test Methods 21
    Purposes of Tests and Field Experience 27
    Data Evaluation and Presentation 29
6. Platform SP65B. 32
    General. 32
    Facilities and Operations 32
    Site Specific Test Program 40
    Operational Data and Observations 40
    Data Presentation and Evaluation 48
7. Platform WD45C. 67
    General. 67
    Facilities and Operations. 67
    Site Specific Test Program 74
    Operational Data and Observations 74
    Data Presentation and Evaluation 83
8. Platform ST177. 103
    General. 103
    Facilities and Operations. 103
    Site Specific Test Program 110
    Operational Data and Observations. 110
    Data Presentation and Evaluation 118
9. Platform BM2C 138
    General. 138
    Facilities and Operations. 138

CONTENTS (continued)

    Site Specific Test Program 144
    Operational Data and Observations. 144
    Data Presentation and Evaluation 150
10. Platform ST131. 168
    General. 168
    Facilities and Operations. 168
    Site Specific Test Program 171
    Operational Data and Observations. 174
    Data Presentation and Evaluation 178
11. Platform BDCCF5 197
    General. 197
    Facilities and Operations. 197
    Site Specific Test Program 199
    Operational Data and Observations. 203
    Data Presentation and Evaluation 205
12. Platform SS107. 224
    General. 224
    Facilities and Operations. 224
    Site Specific Test Program 229
    Operational Data and Observations. 229
    Data Presentation and Evaluation 235
13. Platform SS198G 252
    General. 252
    Facilities and Operations. 252
    Site Specific Test Program 257
    Operational Data and Observations. 257
    Data Presentation and Evaluation 264
14. Platform EI18CF 281
    General. 281
    Facilities and Operations. 281
    Site Specific Test Program 287
    Operational Data and Observations. 289
    Data Presentation and Evaluation 294
15. Platform SM130B 313
    General. 313
    Facilities and Operations. 313
    Site Specific Test Program 318
    Operational Data and Observations. 318
    Data Presentation and Evaluation 324
16. Measurement of Oil Drop Size Distribution 344
    General. 344
    Drop Size Measurement Test Procedure 344
    Sample Points. 347
    Purpose of Tests 348
    Data Presentation and Evaluation 349
17. Discussion of Results 363
    General. 363
    Produced Fluids. 363
    Production Process Systems 365

CONTENTS (continued)

Water Treating Units 365
Effluent Oil Content 365
Flotation Unit Performance 368
Gravity Separator Performance. 372
Brine Soluble Oil. 375
Suspended Solids Tests 381
Sulfate Reducing Bacteria. 381
18. Special Test Evaluations. 382
General. 382
Suspended Solids Tests 382
Filtered Brine Test. 385
Special Oil Content Tests. 394
References 398
Appendix A - Analytical Procedures 399
Oil and Grease Infrared. 399
Oil and Grease Gravimetric 402
Particle Size Distribution 404
Temperature Measurement. 404
pH 406
Boiling Range Distribution 409
Specific Gravity, Oil and Water. 411
Water Cut. 413
Suspended Solids 414
Surface Tension, Oil and Water 417
Silica Gel Adsorption. 420
Viscosity. 423
Susceptibility to Oil Separation 425
Standard Oilfield Ionic Analysis 428
Sulfate Reducing Bacteria. 431
Equilibration 432
Filtered Brine 436
IR Scan of Freon Extracts. 439
Appendix B - Quality Assurance/Quality Control Plan. 440
Analytical Methodology 440
Chain-of-Custody Procedures. 444
Glossary 463

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

FIGURES

Number		Page
1	Generalized schematic of offshore production system	17
2	Production platform location map	20
3	Flow diagram, production process system, SP65B	34
4	SP65B water handling system flow schematic	36
5	SP65B skim tank sketch	38
6	SP65B flotation unit sketch	39
7	Flow chart SP65B skim tank effluent	42
8	SP65B flotation unit performance, GR-oil vs time	50
9	SP65B flotation unit performance, IR-oil vs time	51
10	SP65B flotation unit effluent, GR-oil histogram	52
11	SP65B flotation unit effluent, IR-oil histogram	52
12	SP65B flotation unit effluent, infrared-gravimetric regression	53
13	SP65B flotation unit effluent, total oil - dispersed oil regression	55
14	SP65B flotation unit Freon insoluble suspended solids	59
15	SP65B flotation unit in-out IR-oil regression	60
16	Flow diagram, production process system, WD45C	68
17	WD45C water handling system flow schematic	71
18	WD45C gun barrel 8A & 8B	72
19	WD45C flotation unit sketch	73
20	Flow chart WD45C gun barrel effluents	76
21	WD45C flotation unit performance, GR-oil vs time	85

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

FIGURES (continued)

Number Page

22 WD45C flotation unit performance, IR-oil vs time 86

23 WD45C flotation unit effluent, GR-oil histogram 88

24 WD45C flotation unit effluent, IR-oil histogram 88

25 WD45C flotation unit effluent, infrared-gravimetric regression . 89

26 WD45C flotation unit effluent, total oil - dispersed oil regression 91

27 WD45C flotation unit Freon insoluble suspended solids 94

28 WD45C flotation unit in-out IR-oil regression 95

29 Flow diagram, production process system, ST177 105

30 ST177 water handling system flow schematic 107

31 ST177 gun barrel sketch 108

32 ST177 flotation unit sketch 109

33 ST177 flotation unit performance, GR-oil vs time 120

34 ST177 flotation unit performance, IR-oil vs time 121

35 ST177 flotation unit effluent, GR-oil histogram 122

36 ST177 flotation unit effluent, IR-oil histogram 122

37 ST177 flotation unit effluent, infrared-gravimetric regression . 123

38 ST177 flotation unit effluent, total oil - dispersed oil regression 125

39 ST177 flotation unit Freon insoluble suspended solids 129

40 ST177 flotation unit in-out IR-oil regression 130

41 ST177 flotation unit, hydraulic loading - infrared oil regression 131

42 Flow diagram, production process system, BM2C 140

43 BM2C water handling system flow schematic 142

FIGURES (continued)

Number		Page
44	BM2C corrugated plate interceptor sketch	143
45	BM2C flotation unit performance- GR-oil vs time	151
46	BM2C flotation unit performance, IR-oil vs time	151
47	BM2C flotation unit effluent, GR-oil histogram	152
48	BM2C flotation unit effluent, IR-oil histogram	152
49	BM2C flotation unit effluent, infrared gravimetric regression	153
50	BM2C flotation unit effluent, total oil - dispersed oil regression	155
51	BM2C flotation unit Freon insoluble suspended solids	159
52	BM2C flotation unit in-out IR-oil regression	160
53	BM2C hydraulic loading - infrared oil regression	161
54	Flow diagram, production process system, ST131	169
55	ST131 water handling system flow schematic	172
56	ST131 flotation unit performance, GR-oil vs time	179
57	ST131 flotation unit performance, IR-oil vs time	180
58	ST131 flotation unit effluent, GR-oil histogram	182
59	ST131 flotation unit effluent, IR-oil histogram	182
60	ST131 flotation unit effluent, infrared-gravimetric regression	183
61	ST131 flotation unit effluent, total oil - dispersed oil regression	185
62	ST131 flotation unit Freon insoluble suspended solids	188
63	ST131 flotation unit in-out IR-oil regression	189
64	ST131 flotation unit hydraulic loading - infrared oil regression	190
65	Flow diagram, production process system, BDCCF5	198
66	BDCCF5 water handling system flow schematic	201

FIGURES (continued)

Number Page

67 BDCCF5 flotation unit performance, GR-oil vs time 208

68 BDCCF5 flotation unit performance, IR-oil vs time 208

69 BDCCF5 flotation unit effluent, GR-oil histogram 209

70 BDCCF5 flotation unit effluent, IR-oil histogram 209

71 BDCCF5 flotation unit effluent, infrared-gravimetric regression . 210

72 BDCCF5 flotation unit effluent, total oil - dispersed oil regression 213

73 BDCCF5 flotation unit Freon insoluble suspended solids 215

74 BDCCF5 flotation unit in-out IR-oil regression 216

75 Flow diagram, production process system, SS107 225

76 SS107 water handling system flow schematic 228

77 SS107 flotation unit performance, GR-oil vs time 236

78 SS107 flotation unit performance, IR-oil vs time 236

79 SS107 flotation unit effluent, GR-oil histogram 237

80 SS107 flotation unit effluent, IR-oil histogram 237

81 SS107 flotation unit effluent, infrared-gravimetric regression . 238

82 SS107 flotation unit effluent, total oil - dispersed oil regression 241

83 SS107 flotation unit Freon insoluble suspended solids 243

84 SS107 flotation unit in-out IR-oil regression 244

85 SS107 flotation unit hydraulic loading - infrared oil regression 245

86 Flow diagram, production process system, SS198G 253

87 SS198G water handling system flow schematic 256

88 SS198G flotation unit performance, GR-oil vs time 266

FIGURES (continued)

Number Page

89 SS198G flotation unit performance, IR-oil vs time 266

90 SS198G flotation unit effluent, GR-oil histogram 268

91 SS198G flotation unit effluent, IR-oil histogram 268

92 SS198G flotation unit effluent, infrared-gravimetric regression . 269

93 SS198G flotation unit effluent, total oil - dispersed oil regression 271

94 SS198G flotation unit Freon insoluble suspended solids 274

95 SS198G flotation unit in-out IR-oil regression 275

96 Flow diagram, production process system, EI18CF 282

97 EI18CF water handling system flow schematic 285

98 EI18CF skim tank 286

99 EI18CF flotation unit sketch 287

100 EI18CF flotation unit performance, GR-oil vs time 295

101 EI18CF flotation unit performance, IR-oil vs time 296

102 EI18CF flotation unit effluent, GR-oil histogram 297

103 EI18CF flotation unit effluent, IR-oil histogram 297

104 EI18CF flotation unit effluent, infrared-gravimetric regression . 298

105 EI18CF flotation unit effluent, total oil - dispersed oil regression 300

106 EI18CF flotation unit in-out IR-oil regression 304

107 EI18CF flotation unit hydraulic loading - infrared oil regression 305

108 Flow diagram, production process system, SM130B 315

109 SM130B water handling system flow schematic 317

110 SM130B flotation unit performance, GR-oil vs time 325

FIGURES (continued)

Number Page

111 SM130B flotation unit performance, IR-oil vs time 326

112 SM130B flotation unit effluent, GR-oil histogram 328

113 SM130B flotation unit effluent, IR-oil histogram 328

114 SM130B flotation unit effluent, infrared-gravimetric regression . 329

115 SM130B flotation unit effluent, total oil - dispersed oil regression 331

116 SM130B flotation unit Freon insoluble suspended solids 335

117 SM130B flotation unit in-out IR-oil regression 336

118 SM130B flotation unit hydraulic loading - infrared oil regression 337

119 System Diagram 345

120 Susceptibility to separation 376

121 Susceptibility to separation 377

122 Suspended solids water wash blank studies 387

123 Sample port designation labels 445

124 Hourly sampling schedules 446

125 Completed hourly sampling schedules 447

126 Example of a page from the Analytical Notebook 448

127 Example of a completed page of a notebook used in Phase I research 449

128 TI form 24809. Project-specific data sheet 451

129 Completed TI form 24809 452

130 Calibration log sheets used in Phase I research 453

131 Standard TI sample labels 454

132 TI form 23123, general ecology sample/data progress sheet 456

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

FIGURES (continued)

Number		Page
133	TI form 23120A, general ecology data/displays progress sheet . .	457
134	C-E Crest, TI field analytical data sheet	459
135	C-E Crest, susceptibility of oil to separation data sheet . . .	460
136	C-E Crest, TI laboratory analytical data sheet	461
137	C-E Crest, ionic analysis test sheet	462

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLES

Number Page

1 Characteristics of Platforms Selected for Field Surveys 3
2 Platform Flotation Effluent Oil Content Comparison 5
3 Platform Flotation Unit Performance Comparison 6
4 Platform Gravity Separator Performance Comparison 7
5 Cumulative Percent-by-Number Drop Size Distribution for Composites of Test Runs 8
6 Cumulative Oil Content by Drop Size in Percent 9
7 Cumulative Assigned Oil Content Distribution by Drop Size Groups in Composites of Test Runs 10
8 Characteristics of Platforms Considered for Survey Testing 18
9 Analytical Test Methods 22
10 SP65B Vessel Data Sheet 35
11 SP65B Test Schedule for the Major Brine Tests 41
12 SP65B Average Water Flow Data 43
13 SP65B Well Test Data 44
14 SP65B Vessel Temperatures and Pressures 45
15 SP65B Pressure Drops Through System 46
16 SP65B Chemical Addition 46
17 SP65B Major Brine Tests 49
18 SP65B Flotation Unit Effluent GR-Oil and IR-Oil Comparison 54
19 SP65B Soluble Oil Summary 54
20 SP65B Suspended Solids Tests 57

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLES (continued)

Number Page

21 SP65B Suspended Solids Summary 58
22 SP65B Supplementary Brine Tests 61
23 SP65B Low Pressure Separator Effluent Suspended Solids 62
24 SP65B Sulfate Reducing Bacteria. 62
25 SP65B Water Cut at Various Sample Points 63
26 SP65B Ionic Analysis Flotation Unit Effluent 63
27 SP65B FWKO Effluent Susceptibility to Separation 64
28 SP65B Crude Oil Miscellaneous Tests 65
29 SP65B Crude Oil Boiling Range Distribution 66
30 WD45C Vessel Data Sheet 69
31 WD45C Test Schedule for the Major Brine Tests 75
32 WD45C Well Test Data 78
33 WD45C Vessel Temperatures and Pressures 79
34 WD45C Pressure Drops Through System 79
35 WD45C Chemical Addition 80
36 WD45C Chemical Batch Treatments 81
37 WD45C Day 4 8A Gun Barrel Observations 82
38 WD45C Day 4 Platform Shut In 82
39 WD45C Deck Washing 83
40 WD45C Major Brine Tests 84
41 WD45C Flotation Unit Effouent GR-Oil and IR-Oil Comparison 90
42 WD45C Soluble Oil Summary 90
43 WD45C Suspended Solids Tests 92
44 WD45C Suspended Solids Summary 93

9-1/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLES (continued)

Number Page
45 WD45C IR-Oil Content Summary 96
46 WD45C Combined Gun Barrels Effluent Susceptibility to Separation . . 97
47 WD45C Supplementary Brine Tests 98
48 WD45C Sulfate Reducing Bacteria 99
49 WD45C Water Cut at Various Sample Points 99
50 WD45C Ionic Analysis Flotation Unit Effluent 100
51 WD45C Crude Oil Miscellaneous Tests 101
52 WD45C Crude Oil Boiling Range Distribution 102
53 ST177 Vessel Data Sheet 106
54 ST177 Test Schedule for the Major Brine Tests 111
55 ST177 Well Test Data 112
56 ST177 Vessel Temperatures and Pressures 113
57 ST177 Pressure Drops Through System 113
58 ST177 Chemical Addition 115
59 Tank Bottoms 116
60 ST177 Low Pressure Separator Water Dump 116
61 ST177 Washdowns 117
62 ST177 Rain 117
63 ST177 Major Brine Tests 119
64 ST177 Flotation Unit Effluent GR-Oil and IR-Oil Comparison 124
65 ST177 Soluble Oil Summary 124
66 ST177 Suspended Solids Tests 127
67 ST177 Suspended Solids Summary 128
68 ST177 Gun Barrel Effluent Susceptibility to Separation 132

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
9-1/8"
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLES (continued)

Number Page

69 ST177 Supplementary Brine Tests 133
70 ST177 Sulfate Reducing Bacteria 134
71 ST177 Water Cut at Various Sample Points 134
72 ST177 Ionic Analysis Flotation Unit Effluent 135
73 ST177 Crude Oil Miscellaneous Tests 136
74 ST177 Crude Oil Boiling Range Distribution 137
75 BM2C Vessel Data Sheet 141
76 BM2C Test Schedule for the Major Brine Tests 145
77 BM2C Major Brine Tests 146
78 BM2C Well Test Data 147
79 BM2C Pressure Drops Through System 148
80 BM2C Chemical Addition 149
81 BM2C Flotation Unit Effluent GR-Oil and IR-Oil Comparison 154
82 BM2C Soluble Oil Summary 154
83 BM2C Suspended Solids Tests 157
84 BM2C Suspended Solids Summary 158
85 BM2C Susceptibility to Separation Tests on Gravity Separator Influent 162
86 BM2C Supplementary Brine Tests 164
87 BM2C Brine Tests at Minor Sampling Points 164
88 BM2C Sulfate Reducing Bacteria 165
89 BM2C Ionic Analysis Flotation Unit Effluent 165
90 BM2C Crude Oil Miscellaneous Tests 166
91 BM2C Crude Oil Boiling Range Distribution 167

9-1/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLES (continued)

Number		Page
92	ST131 Vessel Data Sheet	170
93	ST131 Test Schedule for the Major Brine Tests	173
94	ST131 Major Brine Tests	175
95	ST131 Well Test Data	176
96	ST131 Pressure Drops Through System	177
97	ST131 Chemical Addition	177
98	ST131 Flotation Unit Effluent GR-Oil and IR-Oil Comparison	184
99	ST131 Soluble Oil Summary	184
100	ST131 Suspended Solids Tests	186
101	ST131 Suspended Solids Summary	187
102	ST131 Susceptibility to Separation Tests on Gravity Separator Influent	192
103	ST131 Supplementary Brine Tests	193
104	ST131 Brine Tests at Minor Sampling Points	193
105	ST131 Sulfate Reducing Bacteria	194
106	ST131 Ionic Analysis Flotation Unit Effluent	194
107	ST131 Crude Oil Miscellaneous Tests	195
108	ST131 Crude Oil Boiling Range Distribution	196
109	BDCCF5 Bessel Data Sheet	200
110	BDCCF5 Test Schedule for the Major Brine Tests	202
111	BDCCF5 Well Test Data	204
112	BDCCF5 Pressure Drops Through System	205
113	BDCCF5 Flotation Chemical Addition	206
114	BDCCF5 Major Brine Tests	207

TABLES (continued)

Number Page

115 BDCCF5 Flotation Unit Effluent GR-Oil and IR-Oil Comparison 211

116 BDCCF5 Suspended Solids Summary 211

117 BDCCF5 Suspended Solids Tests 214

118 BDCCF Suspended Solids Summary 214

119 BDCCF5 Brine Tests at Minor Sampling Points 217

120 BDCCF5 Susceptibility to Separation Tests on Gravity Separator Influent 219

121 BDCCF5 Supplementary Brine Tests 220

122 BDCCF5 Reducing Bacteria 220

123 BDCCF5 Ionic Analysis Flotation Unit Effluent 221

124 BDCCF5 Crude Oil Miscellaneous Tests 222

125 BDCCF5 Crude Oil Boiling Range Distribution 223

126 SS107 Vessel Data Sheet 227

127 SS107 Test Schedule for the Major Brine Tests 230

128 SS107 Major Brine Tests 231

129 SS107 Well Test Data 232

130 SS107 Pressure Drops Through System 233

131 SS107 Flotation Chemical Addition 234

132 SS107 Chemical Addition 234

133 SS107 Flotation Unit Effluent GR-Oil and IR-Oil comparison 239

134 SS107 Soluble Oil Summary 239

135 SS107 Suspended Solids Tests 242

136 SS107 Suspended Solids Summary 242

137 SS107 Susceptibility to Separation Tests Oil Treater Effluent . . . 247

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLES (continued)

Number Page

138 SS107 Supplementary Brine Tests 248
139 SS107 Ionic Analysis Flotation Unit Effluent 249
140 SS107 Sulfate Reducing Bacteria 249
141 SS107 Crude Oil Miscellaneous Tests 250
142 SS107 Crude Oil Boiling Range Distribution 251
143 SS198G Vessel Data Sheet 255
144 SS198G Test Schedule for the Major Brine Tests 258
145 SS198G Major Brine Tests 260
146 SS198G Well Test Data 261
147 SS198G Pressure Drops Through System 262
148 SS198G Flotation Chemical Addition 262
149 SS198G Chemical Addition 263
150 SS198G Brine Tests on Second Flotation Unit Effluent (9-20) 265
151 SS198G Flotation Unit Effluent (9-10) GR-Oil and IR-Oil Comparison 270
152 SS198G Soluble Oil Summary 270
153 SS198G Suspended Solids Tests 272
154 SS198G Suspended Solids Summary 273
155 SS198G Susceptibility to Separation Tests on Gravity Separator Influent 276
156 SS198G Supplementary Brine Tests 277
157 SS198G Sulfate Reducing Bacteria 278
158 SS198G Ionic Analysis Flotation Unit Effluent (9-10) 278
159 SS198G Crude Oil Miscellaneous Tests 279
160 SS198G Crude Oil Boiling Range Distribution 280

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLES (continued)

Number Page

161 EI18CF Vessel Data Sheet 284

162 EI18CF Test Schedule for the Major Brine Tests 288

163 EI18CF Major Brine Tests 290

164 EI18CF Well Test Data 291

165 EI18CF Pressure Drops 292

166 EI18CF Flotation Unit Effluent GR-Oil and IR-Oil Comparison 299

167 EI18CF Soluble Oil Summary 299

168 EI18CF Suspended Solids Tests 302

169 EI18CF Suspended Solids Summary 303

170 EI18CF Flotation Unit Sludge Drain 306

171 EI18CF Gravity Separator Oil Content 306

172 EI18CF Susceptibility to Separation Tests on Gravity Separator Influent 307

173 EI18CF Supplementary Brine Tests 308

174 EI18CF Brine Tests at Minor Sampling Points 308

175 EI18CF Sulfate Reducing Bacteria 309

176 EI18CF Ionic Analysis Flotation Unit Effluent 309

177 EI28CF Crude Oil Miscellaneous Tests 311

178 EI18CF Crude Oil Boiling Range Distribution 312

179 SM130B Vessel Data Sheet 316

180 SM130B Test Schedule for the Major Brine Tests 319

181 SM130B Major Brine Tests 320

182 SM130B Well Test Data 321

183 SM130B Pressure Drops Through System 322

9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLES (continued)

Number Page

184 SM130B Flotation Unit Effluent GR-Oil and IR-Oil Comparison . . . 330
185 SM130B Soluble Oil Summary 330
186 SM130B Suspended Solids Tests 332
187 SM130B Brine Tests on Low Pressure Separator Effluent (5--0) . . . 333
188 SM130B Suspended Solids Summary 334
189 SM130B Susceptibility to Separation Tests on Gravity Separator Influent 339
190 SM130B Supplementary Brine Tests 340
191 SM130B Sulfate Reducing Bacteria 340
192 SM130B Ionic Analysis Flotation Unit Effluent 341
193 SM130B Crude Oil Miscellaneous Tests 342
194 SM130B Crude Oil Boiling Range Distribution 343
195 Phase I Drop Size Data 350
196 Phase II Drop Size Data 351
197 Phase I Drop Size Run Identification 353
198 Phase II Drop Size Run Identification 354
199 Cumulative Percent-by-Number Drop Size Distribution for Composites of Test Runs 355
200 Cumulative Oil Content by Drop Size in Percent 356
201 Cumulative Assigned Oil Content Distribution by Drop Size Groups in Composites of Test Runs 357
202 Gravity Separator Effluent Drop Size-Oil Content Comparison 358
203 Drop Size Oil Concentration Distribution Summary 360
204 Properties of Produced Fluids 364
205 Production Process Systems 366

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLES (continued)

Number		Page
206	Water Treating Units	367
207	Platform Flotation Effluent Oil Content Comparison	368
208	Soluble Oil Treatability Rating	369
209	Surface Tension Summary	369
210	Platform Flotation Unit Performance Comparison	370
211	Platform Gravity Separator Performance Comparison	373
212	Separator Effluent Oil Content Settling Test Comparison	378
213	Soluble Oil and Water Cut	378
214	Equilibration Tests	380
215	Suspended Solids Blanks on Artificial Brine	383
216	Suspended Solids Blanks Run on Platform Specific Brine	384
217	Suspended Solids Blank Washing Studies	386
218	SS198G Saved Filter Experiment	391
219	SM130B Saved Filter Experiment	392
220	EI18CF Saved Filter Experiment	393
221	BDCCF5 Saved Filter Experiment	394
222	Summary of Saved Filter Tests	395
223	BM2C Flotation Effluent Special Oil Tests	396
224	SS107 Flotation Effluent Special Oil Tests	397
225	Methods for the Analysis of Major Constituents in Oil-Field Waters	430
226	Results of Linearity Test for Horiba OCMA-200	441
227	Labeling Instructions	455

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO METRIC MEASURES

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in.	inches	2.54	centimeters	cm
ft	feet	0.33	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
		MASS (WEIGHT)		
lb	pounds	0.45	kilograms	kg
		VOLUME		
qt	quarts	0.95	cubic decimeters	dm^3
gal	gallons	3.8	cubic decimeters	dm^3
bbl	barrels(42 gal)	0.16	cubic meters	m^3
ft^3	cubic feet	0.028	cubic meters	m^3
		PRESSURE		
psi	pounds per square inch	6.895	kilopascal	kPa
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9(after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
cm	centimeters	0.39	inches	in
m	meters	3.3	feet	ft
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	11.1	square feet	ft^2
		MASS (WEIGHT)		
kg	kilograms	2.2	pounds	lb
		VOLUME		
dm^3	cubic decimeters	1.06	quarts	qt
dm^3	cubic decimeters	0.26	gallons	gal
m^3	cubic meters	6.3	barrels(42 gal)	bbl
m^3	cubic meters	35.	cubic feet	ft^3
		PRESSURE		
kPa	kilopascal	0.145	pounds per square inch	psi
		TEMPERATURE (EXACT)		
°C	Celsius temperature	5/9 (then add 32(	Fahrenheit temperature	°F

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

ABBREVIATIONS AND SYMBOLS

APHA	--American Public Health Association
API	--American Petroleum Institute
API RP	--API recommended practice
ASTM	--American Society for Testing Materials
bbl	--barrel
bpd	--barrels per day
bpd/ft^2	--barrels per day per square foot
°C	--degree Celsius
cc	--cubic centimeter
CE	--chemical electric (treater)
cm	--centimeter
cm^{-1}	--number of wave lengths per centimeter
CPI	--corrugated plate interceptor
D.I.	--deionized
DIA.	--diameter
dm^3	--cubic decimeter (liter)
dm^3/d	--cubic decimeter per day
EPA	--Environmental Protection Agency
°F	--degree Fahrenheit
FBP	--final boiling point
ft	--feet
ft^2	--square feet
FTP	--flowing tubing pressure
FWKO	--free water knock out
g	--gram
g/cm^3	--grams per cubic centimeter
gal	--gallon
G/L	--gas/liquid (separator)
G/O/W	--gas/oil/water (separator)
gpd	--gallons per day
gpm	--gallons per minute
gpm/ft^2	--gallons per minute per square foot
GR	--gravity
GR-Oil	--gravimetric oil (test method or result)
HCl	--hydrochloric acid
HP	--high pressure
HT	--heater treater
IBP	--initial boiling point
in.	--inch
IR	--infrared
IR-Oil	--infrared oil (test method or result)
KBr	--potassium bromide
kg	--kilogram

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

ABBREVIATIONS AND SYMBOLS (continued)

kPag --kilopascal gauge
LACT --Lease Automatic Custody Transfer
LC --level control
LP --low pressure
m_2 --meter
m_3 --square meter
m --cubic meter
Mcfd --thousand cubic feet per day
m^3/d --cubic meters per day
$(m^3/d)/m^2$ --cubic meters per day per square meter
m^3/h --cubic meters per hour
mg --milligram
mg/l --milligrams per liter
min --minute
ml --milliliter
mm --millimeter
MP --medium pressure
n --number of tests
N --normal
No. --number
O.D. --outside diameter of a cylinder
O/W --oil/water (separator)
ppm --parts per million by weight
ppmv --parts per million by volume
psi --pounds per square inch absolute
psig --pounds per square inch gauge
r --correlation coefficient
s --standard deviation
s_Δ --standard deviation of paired values
SEP --separator
SIBHP --shut in bottom hole pressure
sp gr --specific gravity
S.S. --seam to seam or suspended solids
std m^3/d --standard cubic meters per day
TDS --total dissolved solids
TI --Texas Instruments
TSS --total suspended solids
TVD --total vertical depth
Vol. --volume
V/V --volume to volume
w/ --with
W.C. --water column
$\bar{x}$ --mean
$\bar{\Delta}$ --mean difference in paired values
% --percent
μl --microliter
μm --micrometer or micron

ACKNOWLEDGEMENTS

A cooperative effort was required to carry out the study. It was initiated by the United States Environmental Protection Agency based on an earlier program by Exxon Research and Engineering Company.

A preliminary program plan was developed for EPA by Rockwell International acting as Technical Management Services Contractor for EPA. The Oil Industry Offshore Operators Committee provided considerable background information and technical assistance to develop the plan.

Crest Engineering was responsible for conducting the field work and analyzing the data. Texas Instruments was subcontractor for the analytical work. All groups involved helped to develop the detailed program plan.

Five different oil companies provided one or more platforms for the survey. They also provided transportation, living accommodations, work space, utilities, and information on how their facilities were designed and operated. The program could not have been conducted without their cooperation and active participation.

The guidance and advice of EPA's original project officers J. Stephen Dorrler and Frank J. Freestone (Office of Research and Development, Edison, NJ) and John Cunningham (Effluent Guidelines Division) are gratefully acknowledged.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

SECTION 1

INTRODUCTION

The study was conducted to develop information on the oil content of brine discharges from platforms by determining the oil content at various stages and for several consecutive days. The specific objectives were:

1. To define the variability of the oil content of treated brine discharged from offshore Louisiana production platforms,
2. To determine the factors affecting brine oil content variability, and
3. To consider approaches to reduce the oil content of the effluent produced brine.

The general program approach was to conduct ten-day field surveys on ten different platforms. In addition, information on produced fluids, process systems, and operating conditions were recorded to evaluate for their effect on brine oil content.

The minimum test schedule included forty brine effluent gravimetric oil content tests and twenty infrared oil content tests. Oil content tests were also run at upstream points in the production systems. Other tests included in the program either for correlation with oil content, or as indicators of treatability were: soluble oil, oil drop-size distribution, suspended solids, surface tension, filtered brine, and susceptibility to separation. The test procedures and their significances are discussed in Section 5.

Four tests were used as indicators of soluble oily materials. These tests were: silica gel adsorption (IR-Oil w/Silica Gel), filtered brine IR-Oil, equilibration, and IR-Scan of Freon extracts. The IR-Oil w/Silica Gel test proved exceptionally useful for distinguishing between soluble and dispersed oil. As discussed in Section 5, this test is an indicator, not direct measurement of soluble material. Therefore, "soluble" oil and "dispersed" oil are used in this report when referring to the results of the IR-Oil w/Silica Gel test.

Of the ten platforms in the survey, six were in the Bay De Chene, South Pass, West Delta, Bay Marchand and South Timbalier areas in proximity to the Mississippi River delta. The other four were in the Ship Shoal, Eugene Island, and South Marsh Island areas in the Gulf of Mexico south of Morgan City, Louisiana. A map is presented in Section 5.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
6-1/2"
9-1/8"
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

The ten platforms in the survey were selected to represent a wide range with respect to produced fluids, production systems, flotation units, hydraulic loadings, chemicals added, and brine treatabilities. All ten systems had a flotation unit for final treatment. Five flotation design variations were represented. The platforms are listed in Table 1 with descriptive parameters significant to the program.

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 1. CHARACTERISTICS OF PLATFORMS SELECTED FOR FIELD SURVEYS

		Production				Flotation unit			
Platform	Treatability	Oil, m^3/d	Water, m^3/d	Water cut, %	Water treating gravity separator	Manufacturer[(3)] and type	Design loading, m^3/d	Hydraulic[(4)] loading, %	Water treating chemical addition
Phase I									
SP65B	Difficult	1,218	643	35	ST	Wemco (M)	6,135	11	Yes
WD45C	Medium	388	684	64	None(1)	Monosep (H)	981	70	Yes
ST177	Medium	874	763	47	GB	Wemco (H)	2,460	35	Yes
Phase II									
BM2C	Difficult	1,901	720	27	CPI	Wemco (M)	4,090	24	Yes
ST131	Medium	295	138	18	GB	Wemco (M)	1,638	7	Yes
BDCCF5	Easy	180	1,890	91	ST	Monosep (H)	3,180	59	Yes
SS107	Easy	97	633	87	None(2)	Wemco (M)	2,460	30	Yes
SS198G	Medium	94	31	10	CPI	Tridair (H)	795	1.2	Yes
EI18CF	Easy	295	2,709	90	ST	Pollution Control Engineering (D)	10,900	27	No
SM130B	Medium	2,730	631	19	CPI	Wemco (M)	6,135	11	No

(1) Gravity separation was in two gun barrels with the primary function of separating water from oil.

(2) Gravity separation was in a vertical tank oil treater with the primary function of separating water from oil.

(3) Wemco, Tridair, Pollution Control Engineering, and Monosep are registered trade names.
CPI = Corrugated Plate Interceptor.
GB = Gun Barrel.
ST = Skim Tank.
(M) = Mechanical Gas Dispersion
(H) = Hydraulic Gas Dispersion
(D) = Dissolved Gas.

(4) Flow through the unit as the percent of the manufacturer's design loading.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 2

SUMMARY

A summary of brine effluent oil content tests for all ten platforms is presented in Table 2. Means and standard deviations are listed for gravimetric oil (GR-Oil) infrared oil (IR-Oil), soluble oil, and dispersed oil.

A comparison of the performance of flotation units is presented in terms of dispersed oil in the effluent in Table 3. The table also lists influent oil content, hydraulic loading, chemical addition rate, and the flotation unit description for each platform.

A comparison of the performance of gravity separators is presented in Table 4. The table also lists the type of separator, settling test results, the brine/oil specific gravity difference, and brine temperature.

There are significant differences in brine effluent oil content, soluble oil, flotation unit performance, and gravity separator performance of the ten platforms. The reasons for the differences are discussed in Section 17 and conclusions are presented in Section 3.

A summary of drop size distribution tests is presented in Tables 5, 6, and 7 for flotation unit influents and effluents. The tables include listings of median-drop sizes, largest-drop sizes, cumulative number distributions, cumulative concentration distributions in percent, and cumulative concentration distributions in milligrams per liter. The data are discussed fully in Section 16 and conclusions are presented in Section 3.

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 2. PLATFORM FLOTATION EFFLUENT OIL CONTENT COMPARISON

Platform	GR-Oil, mg/l		IR-Oil, mg/l		"Dispersed" oil, mg/l		"Soluble" oil, mg/l		"Soluble" oil, Fraction of IR-Oil
	$\bar{x}$	(s)	$\bar{x}$	(s)	$\bar{x}$	(s)	$\bar{x}$	(s)	%
SS107	7.6	(5.2)	15	(3.7)	1.6	(1.5)	13	(2.7)	87
SS198G	18	(9.2)	36	(7.8)	5.7	(7.7)	31	(2.7)	86
BDCCF5	26	(6.9)	36	(8.3)	26	(8.6)	10	(2.3)	28
ST131	12	(13)	37	(19)	5.9	(13)	28	(3.1)	76
BM2C	22	(6.7)	39	(4.2)	4.9	(5.1)	36	(4.1)	92
SM130B	48	(16)	48	(16)	23	(13)	25	(4.7)	52
EI18CF	52	(24)	76	(38)	63	(30)	13	(13)	17
WD45C	63	(95)	81	(109)	66	(106)	30	(32)	37
ST177	64	(74)	95	(103)	92	(126)	21	(13)	22
SP65B	77	(73)	106	(99)	38	(80)	61	(15)	58

Note: Some numbers do not check because of rounding. Two significant figures have been retained in all numbers below 100.

$\bar{x}$ = Mean
(s) = Standard Deviation

TABLE 3. PLATFORM FLOTATION UNIT PERFORMANCE COMPARISON

Platform	Flotation effluent "dispersed" oil x mg/l	(s) mg/l	Flotation influent total IR-oil x mg/l	(s) mg/l	Hydraulic loading % of design	Flotation chemical addition rate ppmv	Flotation unit description
SS107	1.6	(1.5)	215	(49)	24-31	14	4 - cell (M)
BM2C	4.9	(5.1)	158	(65)	18-39	17	4 - cell (M)
SS198G	5.7	(7.7)	130	(39)	<1-2.5	255	3 - cell (H)
ST131	5.9	(13)	386	(199)	3-12	126	4 - cell (M)
SM130B	23	(13)	156	(105)	1-20	0	4 - cell (M)
BDCCF5	26	(8.6)	113	(15)	59(1)	5	1 - cell (H)
SP65B	38	(80)	170	(147)	11(1)	17	4 - cell (M)
EI18CF	63	(30)	222	(210)	24-30	0	1 - cell (D)
WD45C	66	(106)	1169	(3409)	68-75	7	1 - cell (H)
ST177	92	(126)	432	(394)	26-47	26	4 - cell (H)

Note: (M) = Mechanical gas dispersion
(H) = Hydraulic gas dispersion
(D) = Dissolved gas

(1) Estimated mean.

TABLE 4. PLATFORM GRAVITY SEPARATOR PERFORMANCE COMPARISON

Platform	Water treatment separator type	Effluent IR-oil, mg/l		Settling tests			Hydraulic loading		Brine/oil Δ specific gravity	Brine temperature
				Settling time		Sample(1) point	Tank	CPI		
				5 min	120 min					
		$\bar{x}$	(s)	mg/l	mg/l	-	$(m^3/d)/m^2$	(m^3/d)/plate pack	-	^oC
BDCCF5	Skim Tank	113	(15)	103	53	9--i	27	-	.232	41.1
SS198G	CPI	130	(39)	209	117	8--i	-	10	.258	36.5
SM130B	CPI	156	(105)	169	107	8K-i	-	242	.268	40.9
BM2C	CPI	158	(65)	219	128	8--i	-	580	.262	45.6
SP65B	Skim Tank	170	(147)	311	123	5A30	21	-	.221	33.0
SS107	None(2)	215	(49)	119	86	9--i	120	-	.270	49.2
EI18CF	Skim Tank	222	(210)	151	39	8--i	84	-	.330	39.9
ST131	Gun Barrel	386	(199)	851	239	8--i	8.2	-	.287	22.8
ST177	Gun Barrel	432	(394)	210	100	9--i	31	-	.309	36.6
WD45C	None(3)	1169	(3409)	59	54	9--i	38	-	.133	40.2

(1) Separator influents were sampled if a sample tap was available. Other points and effluents were sampled when influent samples could not be taken.

(2) Gravity separation was in an oil treater with the primary function of separating water from oil.

(3) Gravity separation was in two gun barrels with the primary function of separating water from oil.

TABLE 5. CUMULATIVE PERCENT-BY-NUMBER DROP SIZE DISTRIBUTION FOR COMPOSITES OF TEST RUNS

Platform	Samples[1]	Number of drops	Oil Calculated[2] mg/l	Oil Measured[3] mg/l	Percent-by-number of drops with diameter equal or less than 2 µm %	5 µm %	10 µm %	20 µm %	30 µm %	40 µm %	60 µm %	100 µm %	>100 µm %	Large drops >40	Large drops >60	Largest drop µ
Flotation Influent																
WD45C	399	1,715	53	-	44.5	94.2	99.6	99.97	100.00	-	-	-	-	0	0	25
ST177	340	2,557	277	-	13.0	85.5	98.0	99.5	99.92	99.97	100.00	-	-	3	0	55
BM2C	410	32	9	42	0.01	32.5	89.0	97.3	99.0	100.00	-	-	-	0	0	35
ST131	359	1,537	293	204	3.8	41.0	92.5	99.4	99.88	99.98	100.00	-	-	1	0	49
BDCCF5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS107	410	29	11	99	0.01	32.8	89.0	97.2	99.0	100.00	-	-	-	0	0	35
SS198G	378	1,109	108	51	3.8	54.0	97.0	99.87	100.00	-	-	-	-	0	0	28
EI18CF	365	492	284	189	6.3	45.0	85.6	97.3	99.0	99.55	99.95	100.00	-	11	2	97
SM130B	574	1,231	685	88	6.2	64.0	93.8	98.65	99.05	99.5	99.77	99.94	100.00	41	26	120
Flotation effluent																
WD45C	254	1,637	407[4]	-	57	95.2	98.2	99.4	99.8	99.95	99.95	100.00	-	8	1	64
ST177	512	1,586	35	-	57	97.1	99.63	99.94	99.98	99.98	100.00	-	-	1	0	41
BM2C	410	26	4	9	9	18	91	100.00	-	-	-	-	-	0	0	17
ST131	157	14	7	5	0.01	32.5	85.0	100.00	-	-	-	-	-	0	0	16
BDCCF5	368	565	57	28	25.2	87.8	98.8	99.85	99.94	99.98	99.98	100.00	-	1	1	81
SS107	410	26	4	1	0.01	15.0	93.5	100.00	-	-	-	-	-	0	0	14
SS198G	115	48	26	3	4.0	64.0	94.8	99.42	99.42	100.00	-	-	-	0	0	35
EI18CF	355	629	161	78	5.6	48.0	86.0	98.45	99.9	100.00	-	-	-	0	0	32
SM130B	293	372	50	15	30.3	94.2	99.78	99.78	99.78	99.78	100.00	-	-	3	0	59

(1) Number of brine samples photographed for drop counts.
(2) Oil as calculated from drop counts.
(3) Dispersed oil as measured by IR-Oil w/Silica Gel tests on the brine effluent from the particle-size test equipment when the particle-size-distribution test was run.
(4) Test run during upset conditions.

TABLE 6. CUMULATIVE OIL CONTENT BY DROP SIZE IN PERCENT(2)

			Oil		Percent of oil in drops with diameters equal or less than(2)									Large drops		Largest drop
Platform	Samples(1)	Number of drops	Calculated(2) mg/l	Measured(3) mg/l	2 µm %	5 µm %	10 µm %	20 µm %	30 µm %	40 µm %	60 µm %	100 µm %	>100 µm %	>40	>60	µ
Flotation Influent																
WD45C	399	1,715	53	-	5	44.5	76	92.5	100.00	-	-	-	-	0	0	25
ST177	340	2,557	277	-	0.42	17.5	37.5	60	79	91	100.00	-	-	3	0	55
BM2C	410	32	9	42	0.01	3.0	27.5	46.0	57.0	100.00	-	-	-	0	0	35
ST131	359	1,537	293	204	0.03	6.0	42.8	76.2	90.0	97.0	100.00	-	-	1	0	49
BDCCF5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS107	410	29	11	99	0.01	3.0	26.0	43.0	65.2	100.00	-	-	-	0	0	35
SS198G	378	1,109	108	51	0.06	14.5	70.8	93.0	100.00	-	-	-	-	0	0	28
EI18CF	365	492	284	189	0.02	1.9	10.8	31.0	43.0	56.0	79.5	100.00	-	11	2	97
SM130B	574	1,231	685	88	0.02	1.7	6.8	12.4	15.5	22.8	37.0	65.5	100.00	41	26	120
Flotation Effluent																
WD45C	254	1,637	407(4)	-	1.3	6.6	11.5	27.2	48.8	74.0	94.3	100.00	-	8	1	64
ST177	512	1,586	35	-	7.3	37	55	70	80	87	100.00	-	-	1	0	41
BM2C	410	26	4	9	0.12	2.0	67.0	100.00	-	-	-	-	-	0	0	17
ST131	157	14	7	5	0.01	3.0	48.5	100.00	-	-	-	-	-	0	0	16
BDCCF5	368	565	57	28	0.85	17.4	37.5	46.3	51.5	58.0	58.0	100.00	-	1	1	81
SS107	410	26	4	1	0.01	2.8	80.0	100.00	-	-	-	-	-	0	0	14
SS198G	115	48	26	3	0.07	11.4	31.0	47.0	47.0	100.00	-	-	-	0	0	35
EI18CF	355	629	161	78	0.04	4.2	27.5	71.0	97.8	100.00	-	-	-	0	0	32
SM130B	293	372	50	15	1.1	17.5	24.8	26.0	26.0	26.0	100.00	-	-	3	0	59

(1) Number of brine samples photographed for drop counts.
(2) Oil as calculated from drop counts in milligrams per liter
(3) Dispersed oil as measured by IR-Oil w/Silica Gel tests on the brine effluent from the particle-size test equipment when the particle-size-distribution test was run.
(4) Test run during upset conditions.

TABLE 7. CUMULATIVE ASSIGNED OIL CONTENT DISTRIBUTION BY DROP SIZE GROUPS IN COMPOSITES OF TEST RUNS(1)

			Oil		Assigned concentration of oil in drops w/dia equal or less than (1)									Large drops		Largest drop
Platform	Samples(2)	Number of drops	Calculated(3) mg/l	Measured(4) mg/l	2 µm mg/l	5 µm mg/l	10 µm mg/l	20 µm mg/l	30 µm mg/l	40 µm mg/l	60 µm mg/l	100 µm mg/l	100 µm mg/l	>40	>60	µ
Flotation Influent																
WD45C	399	1,715	53	-	-	-	-	-	-	-	-	-	-	0	0	25
ST177	340	2,557	277	-	-	-	-	-	-	-	-	-	-	3	0	55
BM2C	410	32	9	42	0.0	1.3	11.6	19.3	23.9	42.0	-	-	-	0	0	35
ST131	359	1,537	293	204	0.1	12.2	87.3	155.4	183.6	197.9	204.0	-	-	1	0	49
BDCCF5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS107	410	29	11	99	0.0	3.0	25.7	42.6	64.5	99.0	-	-	-	0	0	35
SS198G	378	1,109	108	51	0.0	7.4	36.1	47.4	51.0	-	-	-	-	0	0	29
EI18CF	365	492	284	189	0.0	3.6	20.4	58.6	81.3	105.8	150.3	189.0	-	11	2	97
SM130B	574	1,231	685	88	0.0	1.5	6.0	10.9	13.6	20.1	32.6	57.6	88.0	41	26	120
Flotation Effluent																
WD45C	254	1,637	407(5)	-	-	-	-	-	-	-	-	-	-	8	1	64
ST177	512	1,586	35	-	-	-	-	-	-	-	-	-	-	1	0	41
BM2C	410	26	4	9	0.0	0.2	6.0	9.0	-	-	-	-	-	0	0	17
ST131	157	14	7	5	0.0	0.2	2.4	5.0	-	-	-	-	-	0	0	16
BDCCF5	368	565	57	28	0.2	4.9	10.5	13.0	14.4	16.2	16.2	28.0	-	1	1	81
SS107	410	26	4	1	0.0	0.0	0.8	1.0	-	-	-	-	-	0	0	14
SS198G	115	48	26	3	0.0	0.3	0.9	1.4	1.4	3.0	-	-	-	0	0	35
EI18CF	355	629	161	78	0.0	3.3	21.5	55.4	76.3	78.0	-	-	-	0	0	32
SM130B	293	372	50	15	0.2	2.6	3.7	3.9	3.9	3.9	15.0	-	-	3	0	59

(1) The cumulative oil concentration data in this table were calculated by multiplying the total analytically determined dispersed oil concentration by the percentage concentration data reported in Table 200.

(2) Number of brine samples photographed for drop counts.

(3) Oil as calculated from drop counts.

(4) Dispersed oil as measured by IR-Oil w/Silica Gel tests on the brine effluent from the particle-size test equipment when the particle-size-distribution test was run.

(5) Test run during upset condition.

SECTION 3

CONCLUSIONS

The first three conclusions below are directly related to the specific objectives listed in Section 1. The ten platforms in the survey were selected to represent a wide range with respect to production methods, production equipment, and brine treatabilities.

1. The present program was successful in developing an oil content data base. The results form an internally-consistent set of data on oil content and related properties on effluent and influent samples taken on a regular schedule from ten separate, offshore platforms for ten consecutive days.

The oil content variability is demonstrated by the ranges of effluent oil contents, of soluble fractions, and of dispersed oils.

2. One restriction limited the realization of the second objective to determine the factors affecting brine oil content variability. The platforms were to be studied as they were usually operated. Nevertheless, this objective was satisfied in part. For example, simple statistical analysis identified soluble oil as a significant variable platform-to-platform, and brine surface tension as a significant variable on any platform. Variations in operating conditions (such as influent oil content, excursions in influent oil content, interruption of flotation chemical, and hydraulic loading) produced notable changes in effluent brine oil content. But no simple statistical correlations were developed.

3. A comparison of gravity separator effluent oil content with the 5- to 120-minute values of the susceptibility to separation test indicated that the equipment was generally operating near those values. Equipment design and operation within the design limits must also be considered in assessing separator performance. A comparison of flotation influent and effluent oil content showed that the flotation units reduced the oil content further, and reduced it below the limit for gravity separators indicated by the susceptibility to separation test. Most flotation units were effective in removing dispersed oil, but their removal efficiencies differed.

4. Special adaptations of six test methods contributed to the successful accomplishment of the project objectives:

a. The infrared method for measuring oil concentrations in brine proved to be acceptable for on-site determinations. Although it gives different results from the gravimetric method, the two are correlatable on a platform-by-platform basis.

b. The silica gel/infrared method for oil and grease analysis provided a measure of the soluble oil content. The soluble oil content at the discharge conditions is a lower limit of treatability by gas flotation.

c. The equilibration method measured brine-soluble components of the crude oils. Results using this method are of the same order of magnitude as those obtained by the silica gel/infrared method.

d. The test for susceptibility to separation proved to be a useful semi-quantitative tool in estimating the ease and ultimate limit of gravity separation.

e. The filtered brine method was intended to provide a measure of soluble oil plus finely dispersed (under 10 μm) oil in the effluent. As such, it could provide an alternative to the silica gel/infrared method in establishing a lower limit of treatability for flotation processes. Differences in experimental procedure caused this method to be inconsistent with the infrared method for determining oil and grease in some cases.

f. Using unique new equipment, oil drop-size distributions were obtained from photomicrographs for both flotation unit influents and effluents. These measurements determined the size range of dispersed oil droplets removed by gas flotation. Dispersed oil concentrations calculated from these distributions compared poorly with measured infrared oil concentrations.

Based on the experience of this project, the first four methods can be used to characterize produced brine. Also, the filtered brine method, after suitable modification, appears promising. The photomicrographic method has application in verifying mathematical models and in improving equipment design.

5. Flow rate data adequate for the minimum needs of this project were obtained through a combination of ingenuity and considerable effort on most platforms. However, the research value of this data set would have been enhanced by a reliable, portable flowmeter.

SECTION 4

RECOMMENDATIONS

SCOPE

The recommendations given here are restricted to those which advance the three specific objectives of this study with the potential of incrementally improving the technology used today.

BACKGROUND

The present project has provided an extensive collection of high quality data which potentially could be used to answer many questions concerning the nature of oil in water and water treating processes. This data base is so large and comprehensive that a major effort will be required to realize its full potential. Produced water treating systems are so complex that a more comprehensive analysis of these data is needed in order to avoid duplication and waste in future work.

One subject that has already been clearly demonstrated to be important in the present work is the type of compounds making up oil in water.

Bulk oil in the stock tank is composed largely of paraffinic, naphthenic and aromatic hydrocarbons with trace amounts of other organic compounds including polar compounds.

The present study found that the flotation influent and effluent contain large quantities of polar organic compounds which adsorb on silica gel.

The study further indicates that the flotation influent and effluent contain organic compounds dissolved in the water phase and dispersed as droplets.

Simultaneous increases in oil content and decreases in brine surface tension suggest that some polar compounds are surface-active agents. These may be concentrated at the oil/water interface between the water phase and oil droplets.

The equilibration test indicates that water in contact with oil in the formation over geologic time contains dissolved compounds, most of which are polar. Flotation effluents probably contain substantial organic compounds which originally were in the dissolved state in the formation.

Reducing the total oil content in discharges involves all three types of organic compounds, bulk dispersed oil, surface-active species at the interface and dissolved compounds.

SPECIFIC RECOMMENDATIONS

1. A comprehensive analysis of the data base provided by the present project must be undertaken. This analysis should include a multivariant analysis of the treatment processes (gravity separation and flotation). The results of the analysis should identify the significant variables affecting the stabilization of oil-in-water and of process unit performance. These variables should be ranked in importance. Possible shortcomings of the various variables should be pointed out (such as limited range of hydraulic loadings in the present work, limited data on variation of chemical treating concentrations, ...). Missing variables of potential importance should be identified (gas to water ratio in the flotation process, ...). No other field studies of treatment processes should be undertaken until this work is complete and its recommendations are known.

2. Methods for characterizing oil in water beyond simply measuring its concentration should be investigated. Some obvious candidates are (1) GLC-boiling point distribution curves such as the method used in the present study to characterize the bulk oil; (2) GLC-MS; and, (3) infrared spectroscopy. Those methods which prove useful could be used to do a parametric study of bulk oils and extracts from a range of water discharge points. Parameters should include: (1) type of solvent for extraction (Freon, polar, nonpolar, ...); (2) pretreatment of sample (bulk separator effluent, gravity separator effluent, flotation cell effluent, ...-all both with and without silica gel treatment); (3) acidification (samples studied as function of naturally occurring pH and with acidification to various predetermined levels); (4) type of chemical treatment given the water (some samples with added chemical treatment and some analyzed as is).

One specific recommendation is to examine the saved Freon extracts from the present project as recommended by the analytical subcontractor after Phase I using the GLC boiling point method and to try and correlate the results with the present data base.

3. Two methods subject to problems during the present study (filtered brine oil in water, flow rate) need more study. The filtered brine method should be modified to be as near as possible to the infrared oil in water method except for the water filtration step prior to extraction. Then this method should be used on a number of discharge points to see if problems encountered in the present study persist.

A search should be conducted for a reliable portable continuous flow rate meter. Process studies are hampered by the lack of a reliable tool for determining this potentially important variable.

SECTION 5

PROGRAM PLAN

OBJECTIVES

The objectives of the overall program were:

... To characterize the brines discharged from offshore platforms with respect to oil content,
... To identify the factors contributing to oil content of the brine, and
... To consider approaches to reduce brine effluent oil content.

The program was planned to be conducted in two phases so that Phase I experience could be used to revise the Phase II Plan. A specific objective for Phase I was to develop recommendations for Phase II.

BACKGROUND INFORMATION

An EPA sponsored study (1) by Exxon Research and Engineering Company identified the oil content of produced brine as the most important parameter to control and proposed a plan to develop a pollution control rationale for offshore oil and gas production.

Previous surveys (2,3) have demonstrated that there are wide variations in oil content of brines from different platforms and of the brine from a single platform at different times. A general conclusion (3) has been that brine oil content is more directly related to brine characteristics, degree of emulsification, droplet size, suspended solids concentration, and other factors than to the sophistication of the treatment system. A limitation of previous surveys has been that little information on factors contributing to oil content has been available for correlation with measured oil contents.

An earlier EPA report (4) concluded that gravity separation followed by dissolved gas flotation represented Best Demonstrated Technology.

TECHNICAL APPROACH

The approach to meeting the program objectives was to conduct ten-day field surveys on ten platforms, three during Phase I and seven during Phase II. A major part of the testing was directed to defining the variability of brine effluent oil content. Special tests were run to determine whether the oil in the brine was soluble, dispersed in fine droplets, or associated with suspended solids. Information on the design and operation of the water treating

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTION HERE

systems was recorded for correlation with brine oil content test data.

The field survey testing schedules were developed in a step-wise manner. Before the program was started, the EPA Program Officer developed a preliminary program plan based on the Exxon draft report (1). The Exxon report and the preliminary program plan included a generalized schematic of an offshore production system, Figure 1. As a guide, the preliminary plan identified sample points and the tests to be run at each sample point. One requirement was to run forty oil content tests by the gravimetric procedure and forty by the infrared procedure on the brine effluent from each platform.

The preliminary plan recommended the analytical procedures to be used. The procedures and the general significance of each are discussed in later paragraphs in this section.

Three platforms were selected for Phase I survey testing to represent a variety of conditions with respect to water cuts, lift methods, processing schemes, chemical addition, difficulty of treatment and polishing units (type of flotation unit).

6-1/2"

Platform Selection

The objective in platform selection was to pick platforms representing a wide spectrum with respect to factors considered to have the most influence on effluent oil content. The factors chosen for highest priority were brine treatability, gravity separator type, and flotation unit type and hydraulic loading. Other factors considered were lift method, water cut, characteristics of produced fluids, processing systems, and chemical addition programs. Platforms with flow monitors were selected if other criteria were met.

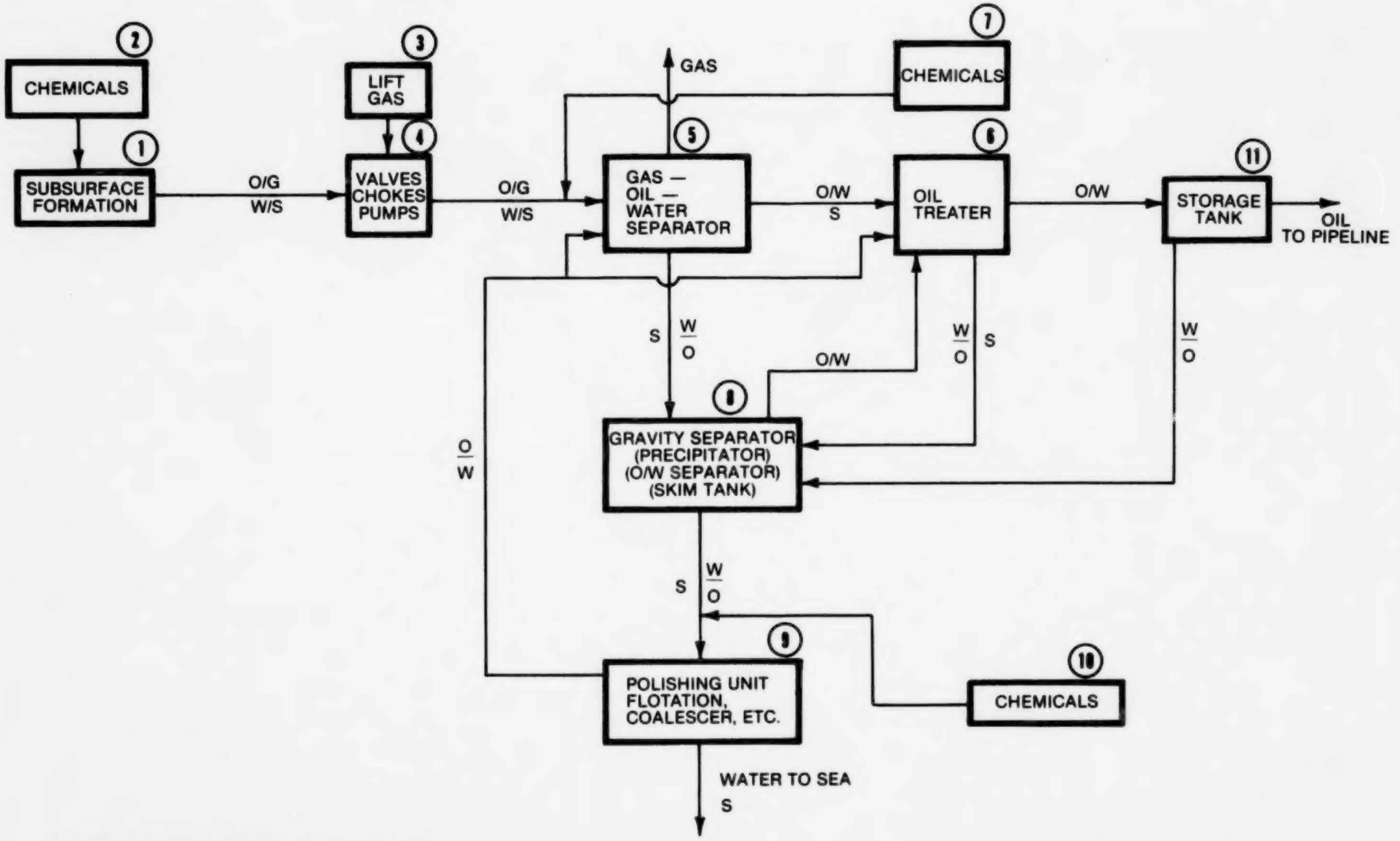
Following is a listing of technical criteria used for platform selection:

-- Treatability
-- Lift method
-- Water cut
-- Process complexity
-- Chemical addition
-- Gravity separator type
-- Flotation unit type
-- Flotation unit hydraulic loading

A non-technical criterion was that platforms selected have living quarters. Meeting testing schedules would be much more difficult and expensive if the survey team could not stay on the platform. One of the ten survey platforms did not have quarters.

Before selecting platforms for the survey, fifty-five were reviewed based on information provided by the operators. Information on higher priority selection criteria are listed in Table 8 for all platforms considered. The platforms selected for Phase I and Phase II surveys are listed at the top. One platform, EI175C, selected for the Phase II survey became unavailable for operational reasons and was replaced by Platform SM130B.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"


CHEMICALS
②
SUBSURFACE FORMATION
①
O/G
W/S
LIFT GAS
③
VALVES CHOKES PUMPS
④
O/G
W/S
GAS
GAS — OIL — WATER SEPARATOR
⑤
CHEMICALS
⑦
O/W
S
OIL TREATER
⑥
O/W
STORAGE TANK
⑪
OIL TO PIPELINE
S
W/O
O/W
W/O
S
W/O
GRAVITY SEPARATOR (PRECIPITATOR) (O/W SEPARATOR) (SKIM TANK)
⑧
O/W
S
W/O
POLISHING UNIT FLOTATION, COALESCER, ETC.
⑨
CHEMICALS
⑩
WATER TO SEA
S

- ARROWS SHOWN DIRECTION OF FLUID FLOW.
- LETTERS ALONGSIDE ARROWS INDICATE MATERIALS PRESENT IN THAT STREAM.
- LETTERS ARE ARRANGED IN ORDER OF DECREASING CONCENTRATION OF EACH COMPONENT — E.G., O/G/W CODE: OIL — GAS — WATER.

Figure 1. Generalized schematic of offshore production system.

TABLE 8. CHARACTERISTICS OF PLATFORMS CONSIDERED FOR SURVEY TESTING

Platform identification	Brine treatability	Production rate			Water cut	Gravity[1] separator	Polishing unit				
		Oil m^3/d	Gas std m^3/d	Water m^3/d	%		Manufacture[2] or trade name	Model	Type[3]	Design capacity m^3/d	Hydraulic loading % of Design
Platforms Selected for Phase I											
SP65B	Difficult	1,934	420,000	574	23	ST	Wemco	84	Disp.(M)	6,135	9
WD45C	Medium	556	86,000	445	44	None	Monosep	AG-6000	Disp.(M)	954	47
ST177	Medium	922	566,000	827	47	GB	Wemco	66	Disp.(H)	2,460	34
Platforms Selected for Phase II											
BM2C	Difficult	2,469	783,000	1,064	30	CPI	Wemco	76	Disp.(M)	4,090	26
ST131	Easy	716	424,000	318	31	GB	Wemco	56	Disp.(M)	1,638	19
BDCCF5	Difficult	410	277,000	2,652	87	ST	Monosep	AG-20,000	Disp.(H)	3,180	83
SS107	Difficult	779	170,000	2,067	73	None	Wemco	66	Disp.(M)	2,460	84
SS198G	Difficult	-	-	159	-	CPI	Tridair	DC500	Disp.(H)	795	20
EI18CF	Easy	364	48,000	2,750	86	ST	PCE	-	Diss.	7,950	34
SM130B	Medium	2,730	237,000	631	19	CPI	Wemco	84	Disp.(M)	6,135	11
EI175C[4]	Medium	424	83,000	1,706	80	ST	Wemco	84	Disp.(M)	6,135	28
Other Platforms Considered For Survey Testing											
V214A	Difficult	986	623,000	795	45	ST	Wemco	66	Disp.	2,460	33
V119D	Medium	318	134,000	286	47	ST	Monosep	AG-6000	Disp.(H)	954	30
SS206A	Difficult	48	283,000	56	54	ST/CPI	Wemco	36	Disp.	273	20
V124E	Medium	318	149,000	223	41	ST/CPI	Monosep	AG-3000	Disp.(H)	477	47
WC69A	Difficult	29	424,000	17	37	ST	Monosep	AG-3000	Disp.(H)	477	37
EC266C	Easy	25	28,000	16	39	None	Monosep(H)	AG-1000	Disp.(H)	159	10
SMI23A	Difficult	32	156,000	159	83	ST	Wemco	36	Disp.	273	33
SMI23R	Difficult	64	708,000	64	50	ST	Hyde	12	Coal.	343	19
SS154E	Difficult	636	85,000	795	56	None	Wemco	44	Disp.	819	97
SS169A	Difficult	32	340,000	64	67	None	Hyde	4	Coal.	151	42
ST151A	Medium	1,749	708,000	3,975	69	-	Wemco	84	Disp.	6,135	65
EI238E	Medium	413	246,000	3	<1	ST	Hyde	12	Coal.	343	<1
EI238A	Medium	64	142,000	3	5	None	Hyde	12	Coal.	343	<1
EI330B	Difficult	2,353	615,000	176	7	CPI	Wemco	76	Disp.(M)	4,090	4
WD105C	Medium	332	80,000	919	73	None	Wemco	84	Disp.(M)	6,135	16
MP35	Medium	413	65,000	5,088	92	ST	PCE	750	Diss.	3,975	>100
EB24,27,28	Medium	5,883	1,556,000	27,825	83	ST	-	-	Diss.	11,925	>100
WI(WF)	Medium	1,495	1,274,000	8,109	84	ST	PCE	-	Diss.	6,360	43
							Wemco	84	Disp.(M)	6,135	88
EI276C	Medium	572	1,868,000	1,749	75	ST	CE Natco	SPX	Diss.	6,201	28
WD30E	Medium	542	215,000	2,319	81	ST	CE Natco	SPX	Diss.	6,201	37
BM2A	Difficult	334	255,000	251	43	ST	Wemco	56	Disp.(M)	1,638	15
EI330A	Difficult	969	329,000	452	32	CPI	Wemco	76	Disp.	4,090	11
SP65A	Difficult	1,032	199,000	767	43	ST	CE Natco	SPX	Diss.	6,200	12
V247A	Easy	175	1,415,000	151	46	CPI	Wemco	56	Disp.	1,638	9
SP62A	Medium	528	151,000	349	40	ST	CE Natco	SPX	Diss.	6,200	7
SP62B	Medium	1,168	363,000	172	13	ST	CE Natco	SPX	Diss.	6,200	3
MP69C	Medium	1,272	255,000	5,883	82	ST	PCE	750	Diss.	3,975	>100
WI (EF)	Medium	64	51,000	1,590	96	ST	PCE	-	Diss.	1,908	83
V164B	Easy	111	30,000	130	54	ST	Wemco	56	Disp.	1,638	8
MP290A	Medium	489	151,000	1,401	76	ST	CE Natco	SPX	Diss.	6,200	23
SS274A	Easy	89	113,000	326	79	None	Wemco	56	Disp.	1,638	20
EI188A	Medium	88	10,000	355	80	-	Wemco	55	Disp.	1,638	22
EI188B	Medium	190	45,000	456	71	ST	PCE	-	Diss.	2,727	17
EI276B	Easy	52	91,000	509	91	ST	PCE	-	Diss.	1,359	37
SP62C	Easy	-	-	317	-	ST	CE Natco	SPX	Diss.	6,200	5
WD105A	-	113	65,000	566	83	None	CE Natco	-	Diss.	3,180	18
EI128A	Medium	210	29,000	258	55	None	Wemco	44	Disp.	819	31
EI100CF	Easy	52	29,000	141	73	None	Wemco	44	Disp.	819	17
SMI73B	Easy	3,125	227,000	587	16	ST	PCE	-	Diss.	3,816	15
WCBB3	Difficult	525	42,000	2,624	83	ST	Monosep	AG-20,000	Disp.	3,180	83
CBIB1	Difficult	318	110,000	1,749	85	ST	Monosep	AG-20,000	Disp.	3,180	55
GMCF3	Medium	41	-	178	81	ST	CE Natco	SPX	Disp.	954	19
QBICF3	Difficult	16	945,000	205	93	ST	Monosep	AG-3000	Disp.	477	43
GIB600	Difficult	119	45,000	425	78	ST	Monosep	AG-6000	Disp.	954	45

(1) ST = Skim Tank. CPI = Corrugated Plate Interceptor. GB = Gun Barrel

(2) Wemco, Monosep, CE Natco, Tridair, Hyde, and Pollution Control Engineering (PCE) are either company names or registered trade names.

(3) Disp. = Dispersed gas flotation. Diss. = Dissolved gas flotation. Coal. = Coalescer. M = Mechanical gas dispersion. H = Hydraulic gas dispersion

(4) EI175C was selected for testing but was not available when needed and was replaced by SM130B.

All data in Table 8 are preliminary planning estimates and do not necessarily match conditions at the time of the survey as presented in other parts of the report. The brine treatability ratings are operators estimates based on field experience. The ratings in Table 1 are based on this survey test results for soluble oil, the more soluble oil the more difficult to treat. Both rating methods are empirical. In both cases there is a good balance between platforms with easy, medium and difficult to treat brine.

Gravity separators of three types and flotation units with five different design variations were included in the survey. The range of hydraulic loading of flotation units selected was from 9 to 84 percent of design rating.

Location and General Information

All of the platforms considered for the survey were in the Louisiana Gulf Coast area. Figure 2 is a location map. To illustrate diversity, one platform, SM130B, was over 140 kilometers from shore and had been in production less than two years. Another platform, BDCCF5 was in a marshy area and had been in production about twenty-five years. BDCCF5 was the only platform without quarters.

All platforms selected were producing oil, gas, and water. The number of wells producing oil per platform varied from one to thirty at the time of the survey. The locations of the survey platforms are shown in Figure 2 in relation to important areas of production.

The platforms studied were located where the large hydrocarbon accumulations were mostly associated with salt domes or anticlines overlying various salt masses (5).

The Bay Marchand-Timbalier Bay-Caillou Island salt dome complex is more than 47 km long and 7 to 20 km wide with 3 domes derived from a common Triassic-Jurassic salt mass penetrating to within 600-1000 meters of the surface and forming a variety of associated traps in sandstones of Pliocene to to Miocene age.

Eugene Island, South Pass, South Timbalier and West Delta are other major offshore oil or gas accumulations with Tertiary sandstone reservoirs. Practically all known types of traps occur in connection with salt dome structures (6). These include:

1. One simple domal anticline.
2. Graben fault trap over dome.
3. Porous cap rock of limestone or dolomite.
4. Flank sand pinchout and sand lens.
5. Trap beneath overhangs.
6. Trap uplifted and buttressed against salt plug.
7. Unconformity.
8. Fault trap downthrown away from dome.
9. Fault downthrown toward dome.

The characteristics of produced fluids from other locations and other

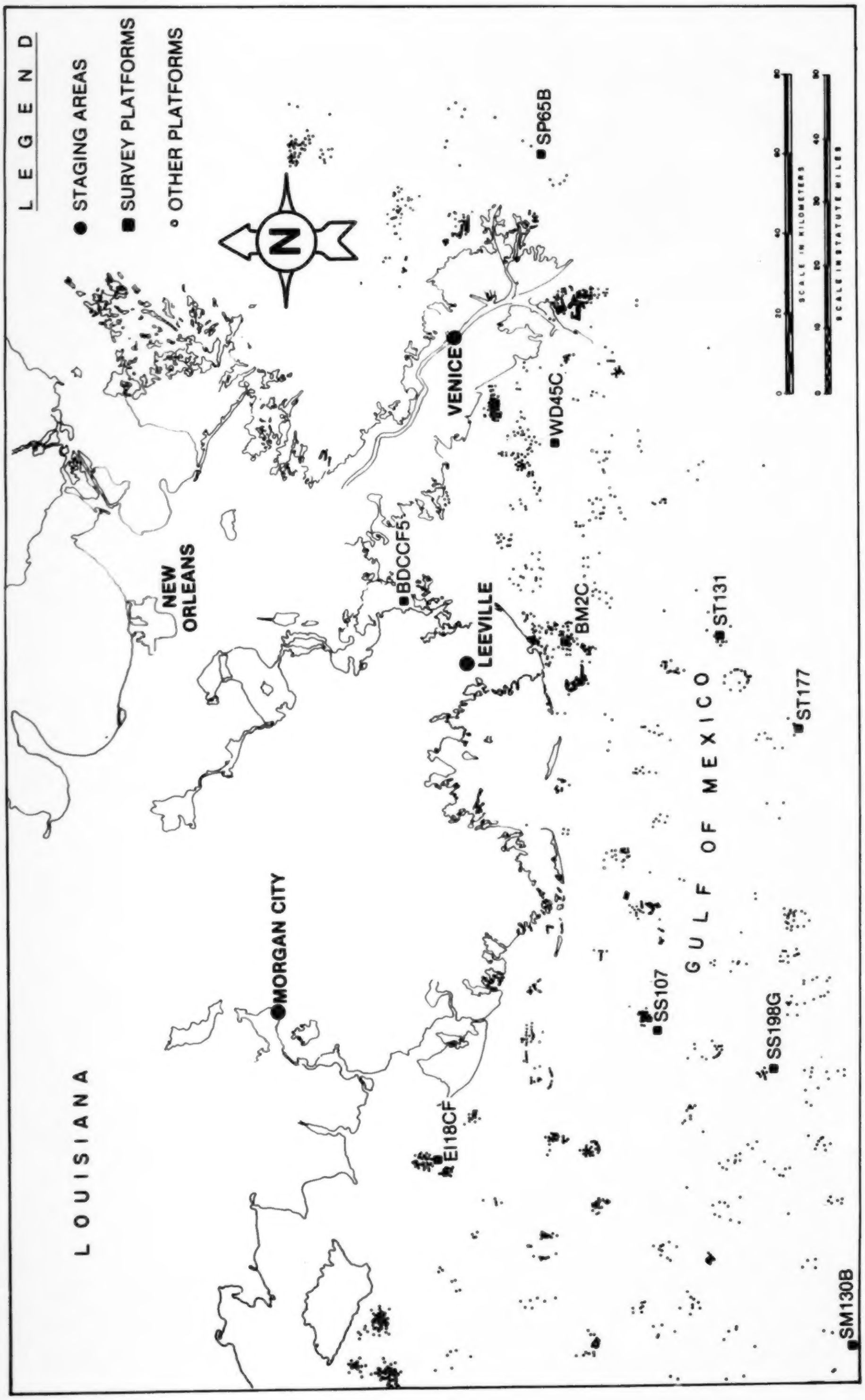

LEGEND
● STAGING AREAS
■ SURVEY PLATFORMS
∘ OTHER PLATFORMS
N
LOUISIANA
MORGAN CITY
NEW ORLEANS
LEEVILLE
VENICE
BDCCF5
BM2C
WD45C
SP65B
ST131
ST177
SS107
SS198G
EI18CF
SM130B
GULF OF MEXICO
SCALE IN KILOMETERS
0 20 40 60 80
SCALE IN STATUTE MILES
0 10 20 30 40 50

Figure 2. Production platform location map.

EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET

formations may be different from those included in this survey. Little information is generally available on the amount of soluble oil and surface active compounds present in the brine from various locations and formations. It is known that there are differences that could have a significant effect on oil/water separation.

Operational Characteristics

In addition to analytical testing, the program plan included collecting available information on produced fluids and on the design and operation of production facilities to evaluate for correlation with brine oil content. The characteristics of produced fluids, chemical usage, design and operating conditions of the processing system, and upsets and intermittent operational procedures were of special interest.

A general but more detailed list of the types of information to be recorded is as follows:

Well Data	Processing Data
Formation identification	For vessels design and operating
Total vertical depth	
Production rates	Flow rate
Oil	Temperature
Water	Pressure
Gas	Residence time
Water cut	Overflow rate
Lift method	
Lift gas	Chemical addition
Shut in bottom hole pressure	
Flowing tubing pressure	Upsets
Choke size	
Gravity of oil	Intermittent operational or maintenance procedures
Receiving vessel	
Chemical injection	Unplanned events

Information on the above factors was to be obtained by observations and measurements by the field survey team, from company records, and by verbal reports from operating personnel.

ANALYTICAL TEST METHODS

Standard analytical test methods were employed for a majority of the testing program. Procedures published by the U. S. Environmental Protection Agency, American Society for Testing and Materials, American Public Health Association, American Petroleum Institute and special procedures adapted for this program were used.

Table 9 presents a listing of parameters measured, method(s) used and applicable references. The complete procedure for each test is presented in this report in Appendix A. The purposes of the tests and field experience

EPA-287 (Cin.)
(4-76)

TABLE 9. ANALYTICAL TEST METHODS

Parameters	Method	Reference[1]
Oil & Grease	Infrared (Storet 00560)	EPA
	Gravimetric	EPA
Temperature	Thermometer	ASTM
pH	Combination Electrode	ASTM
Boiling Range Distribution	Gas Chromatography	ASTM
Specific Gravity	Hydrometer	ASTM
Water Cut	Volumetric	ASTM
Suspended Solids	Gravimetric	EPA, ASTM
Surface Tension	Surface Tensiometer	ASTM
Viscosity	Viscometer	ASTM
Crude Oil Solubility	Silica Gel Adsorption	APHA
	Equilibration	Shell Oil Company
	Filtered Brine	Mobil Oil Corp.
	IR Scan	EPA
Susceptibility to Separation	Infrared	Conoco, Inc.
Ionic Analyses Sodium, Potassium	Flame Emission	API
Iron, Calcium Magnesium	Atomic Absorption	EPA
Barium		API
Chloride, Sulfate	Autoanalyzer	APHA
Total Dissolved Solids	Gravimetric	EPA
Sulfide	Iodometric Titration	APHA
Alkalinity	Electrometric Titration	API
Bacterial Culture	Sulfate Reducing	API
Particle Size Distribution	Photomicrographic	Section 16

---

(1) More detailed references in Appendix A.

with them are discussed in a following subsection.

Oil and Grease Determination - Infrared

Total recoverable oil and grease determinations were made onboard the platforms according to U. S. EPA procedures substituting a Horiba OCMA-200 IR analyzer for the EPA recommended double-beam recording IR spectrophotometer. The Horiba instrument was a portable non-dispersive IR analyzer especially suited to work on offshore platforms. Linearity in the concentration range 0-100 ppm (V/V) was verified prior to use of the equipment offshore.

Analysis of brine was accomplished by acidification with HCl or H_2SO_4 to pH 2, extraction three times with 30 ml Freon TF, filtration of the Freon through Whatman 40 filter paper and IR analysis of the Freon extract. Preliminary oil and grease data were reported in μl oil/l brine (ppmv). Concentrations were converted to mg oil/l brine using specific gravity data.

Oil and Grease Determination - Gravimetric

Samples of brine were also extracted for analysis of total recoverable oil and grease by gravimetric techniques. Separate brine samples were processed on the platforms in a manner identical to IR samples. The Freon extracts were returned to the onshore laboratory in glass bottles sealed with teflon-lined screw caps. Samples were transferred to round-bottom evaporation flasks. The Freon was stripped off using a 70°C water bath. The contents were dried in an 80°C water bath, and N_2 was used to purge the flask of remaining solvent. The flasks were cooled in a desiccator for 30 minutes and weighed. Gravimetric oil and grease concentrations were reported in mg oil/l brine.

Temperature

Temperature measurements were accomplished utilizing dial thermometers calibrated against mercury thermometers. Since system temperatures were usually higher than the ambient air temperatures, this technique did suffer somewhat from inaccuracies in temperature equilibration under non steady state conditions. However, the error limits are estimated to be ± 0.75°C.

pH

Measurement of pH was accomplished utilizing a Type 1 battery-operated pH meter (ASTM, 1978). The response of the combination electrode was verified every second day. The electrode was replaced whenever the response slope was less than 95 percent of the Nernst slope. The battery powered pH meters proved to be less reliable than desired. Error limits of ± 0.5 pH units are likely to exist.

Crude Oil Boiling Range Distribution

Crude oil samples were collected onboard each platform for a determination of the boiling range distribution. Samples were returned to the laboratory and analyzed by gas chromatography. Initial boiling point (IBP), final boiling point (FBP), and cumulative area percent for each 50°C interval from IBP to FBP were reported for each sample.

Specific Gravity

Crude oil and brine specific gravities were measured using hydrometers conforming to ASTM design. Readings were taken as soon as possible after the sample was collected to ensure that specific gravity data reflected applicable system conditions. Temperature data were also taken.

Water Cut

Determinations of the percent water and sediment in produced fluids were made according to ASTM D 1796-68 (1973) without modification.

Suspended Solids

Suspended solids data were generated following the EPA Storet Method No. 00530 using Gelman A glass fiber filters. Quality control techniques according to ASTM Standard Test Method D 1888-67 (1974) were employed. Samples were collected onboard the platforms using inline filter holders to prevent oxidative production of suspended solids. Volumes filtered ranged from 50-1000 ml depending on where the samples were collected in the system. After the samples were taken, all filters were washed with 50 ml of deionized water, removed from the filter holder, and placed in clean plastic petri dishes. The dishes were placed in the onboard freezers until all platform work was completed, subsequently transported to the TI Dallas laboratories on ice and stored in laboratory freezers until analysis. Results (mg/l) were reported as total suspended solids, total Freon-soluble material, total acid-soluble material (6NHCl), and residual suspended particulate material.

Surface Tension

Crude oil and brine surface tension measurements were made according to ASTM Standard Test Method D 1590-60 (1977) utilizing Fisher Scientific Company Model 20 Tensiometers. Fisher Vibradamp® balance supports were also used to ensure low vibration operation. As employed, these vibration dampers eliminated machinery-associated platform vibration so that representative surface tension measurements could be made. Temperature was measured but not controlled. The measured surface tension was adjusted to the surface tension at the sampling temperature by the Othmer relation (10). When tests were run on samples taken upstream of the flotation unit, the free oil was removed by static settling in a separation funnel before the surface tension test was run.

Silica Gel Adsorption

Measurements to determine adsorbable hydrocarbons in Freon extracts on 2 percent deactivated silica gel were made according to APHA Standard Method 502E, Hydrocarbons (7). Oil and grease determinations were performed using the Horiba IR analyzer, as previously described. Results were reported as concentration of the remaining hydrocarbons (mg/l) after adsorption.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Crude Oil Equilibration

Equilibration tests were run by a procedure supplied by Shell Oil Company which is presented in Appendix A. A layer of crude oil was placed on top of a layer of brine in a 4,000 ml flask so that the two layers were not mixed. The flask was then held in an oven at 82°C for fourteen days. A sample of the brine was then taken for an IR-Oil content measurement. For Phase I tests a synthetic brine equivalent to a concentration of 100,000 mg/l was used. The oil/water volume ratio was four oil to one water.

For Phase II testing, the brine concentration was the same as that of the produced brine of the particular platform. One equilibration test was run with the same oil/water ratio as the produced fluids. A second test was run with a 4/1 oil/water ratio.

Filtered Brine

Water samples were filtered through Whatman No. 40 filters to remove large dispersed oil droplets. Soluble oil and some of the finely dispersed oil would pass through the filter. According to the 1979 Fisher Scientific Co. catalog (pp. 321), the Whatman 40 filter removes particles of about 8-μm size.

After filtering, the filtrate was analyzed for filtrable hydrocarbons following the previously discussed technique for IR determination of oil and grease.

Following are differences in the filtered brine and the standard IR-Oil test for oil and grease:

1. Sample volume:

   Filtered Brine Test - 50 ml
   Standard IR-Oil Test - 1000 ml

2. Sample/Freon Extract Ratio:

   Filtered Brine Test - 50 ml sample/50 ml Freon
   Standard IR-Oil Test - 1000 ml sample/90 ml Freon

3. Filtering of Freon Extract Before Measuring Absorbance:

   Filtered Brine Test - Freon not filtered.
   Standard IR-Oil Test - Freon filtered.

IR Scan of Addition Chemicals and Freon Extracts

Infrared scans of addition chemicals and selected Freon extracts were made using a Perkin-Elmer Model 621 scanning infrared spectrophotometer. Addition chemicals without water were run using 0.1 or 0.05 millimeter cells or salt plates. In the case of addition chemicals in water solution, the water was evaporated from the sample using a heat lamp, the residual material

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

was incorporated into a KBr pellet and the scan was made. All scans were run from 4000-550 cm^{-1}. Attenuation was adjusted so that the largest peak in the scan remained on scale.

Viscosity

Crude oil viscosity measurements were made following ASTM Standard Test Method D 445-74 using calibrated Cannon-Fenske viscometers. For each crude oil sample, the kinematic viscosity was determined experimentally and the dynamic viscosity was calculated using crude oil densities taken at the same temperature as used for determining viscosity.

Susceptibility to Oil Separation

The susceptibility to separation (settling) tests were run by a procedure supplied by Conoco Inc. Several samples were taken each in a different separatory funnel. The brine oil content was then measured after various defined settling times. The IR-Oil test previously described was used. For Phase I testing, the settling times were 1, 5, 15, 30, 60 and 120 minutes.

For Phase II testing the settling times were 2, 5, 15, 30, 60 and 120 minutes. Zero-settling-time control samples were taken immediately before and after taking the settling test samples.

Standard Oilfield Ionic Analysis

Table 9 presents the methods for the analysis of major constituents in oil field waters. Standard methods were utilized throughout for flame emission and atomic absorption spectrophotographic analyses. The atomic absorption analyses were made using a flame source for calcium and magnesium; iron and barium analyses were made using a heated graphite atomizer source. Standard addition analyses, blank and background corrections, and spiked sample analyses were conducted for each determination.

Bacterial Culture: Sulfate-Reducing Bacteria

The technique for determination of sulfate-reducing bacteria follows the alternative technique (API RP 38) for estimating sulfate-reducing bacteria. Sample bottles with the nutrient agar and acid-etched iron nails were prepared and autoclaved in the laboratory. Bottles were again sterilized immediately prior to use so that the agar would be liquid and mixing of the inoculum could be done. Bacterial samples were held onboard the platforms in portable incubators set within 5°C of the recorded temperature of the brine water at the time of sampling. Samples were transported to the TI Dallas laboratories in insulated containers. The incubation continued for a total of four weeks in laboratory incubators. All bacterial samples were prepared in duplicate. Results were reported as a range in numbers i.e., 100-1000 sulfate-reducing bacteria per milliliter.

Particle Size Distribution

Particle-size distribution tests were run by a new non-standard procedure

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

which is described in Section 16. Brine samples were taken from a flowing stream into a cell where the flow was stopped just long enough to take photomicrographs of the particles present. The procedure has the capability to distinguish between solids, oil droplets, and gas bubbles.

For Phase II testing, a sample of the brine from the photomicrograph test unit was taken during each run for oil content tests. This was not done during Phase I.

PURPOSES OF TESTS AND FIELD EXPERIENCE

Each test used had a purpose in meeting the Program objectives. All the tests were either for measuring brine oil content or for measuring parameters that could influence the oil content.

Test development work was not included in the Program Plan. For the most part, standard tests were used and they proved effective in meeting the Program objectives. Problems were experienced with certain tests in the field that limited their value. The major tests and the tests with which problems were experienced are discussed in this subsection.

Standard Oil Content Tests

The standard infrared and gravimetric oil content procedures were used to determine the level and variability of brine oil content. These procedures were completely satisfactory for the intended purposes.

IR-Oil w/Silica Gel Test

The IR-Oil w/Silica Gel test was used as an indicator of polar water-soluble-type compounds in the brine. Various investigators (7,8,9) have shown that hydrocarbon oils in Freon are adsorbed on silica gel only to a very limited extent, whereas naphthenic acids, vegetable oils and other polar compounds having significant water solubility are adsorbed under the test conditons. To the extent that the IR-Oil w/Silica Gel test is a true indicator of solubility, it is also an indicator of a lower level of treatability by physical processes. The IR-Oil and corresponding IR-Oil w/Silica Gel tests were run on the same Freon extracts. The term "soluble" oil is used in this report for the material extracted by silica gel. The term "dispersed" oil is used for the unextracted material.

When applied to flotation unit effluents with IR-Oil contents typically less than 100 mg/l, the IR-Oil w/Silica Gel tests indicated that the amount of "soluble" oil present was relatively uniform from sample to sample on each platform. This consistency, which was expected, enhanced the confidence that could be placed in the test results. The IR-Oil w/Silica Gel test was considered very useful in indicating the proportion of "soluble" oil and "dispersed" oil in effluents.

During Phase II only, the IR-Oil w/Silica Gel test was run on samples taken upstream of the flotation unit. The IR-Oil contents were typically above 100 mg/l and fluctuated widely from sample to sample.

The filtered brine IR-Oil tests on upstream samples on most platforms indicated less soluble oil was present than was indicated by the IR-Oil w/Silica Gel tests.

Because of conflicting data, no attempt is made in this report to draw conclusions about differences in soluble oil in the brine at different points in the production systems. The IR-Oil w/Silica Gel test data and the filtered brine test data on the flotation effluent and at upstream sampling points are presented in a single table for comparison in each individual platform section.

IR-Oil Filtered Brine Test

The IR-Oil filtered brine test was used as an indication of treatability. Brine was filtered through Whatman No. 40 filter paper. Then the IR-Oil content of the filtrate was measured. Only soluble oil and very fine droplets were expected to pass through the filter.

The filtered brine survey test results were not always consistent with the IR-Oil results. The mean oil content of flotation effluent filtered brine was higher than that of unfiltered brine for five platforms. For one platform, the mean oil content of filtered brine was 30 mg/l higher. The mean oil content of flotation effluent filtered brine was lower than that of unfiltered brine on the other five platforms. For one platform, the mean filtered brine oil content was 63 mg/l lower.

A possible explanation for high filtered brine oil content is that the Freon extract of some brines retains a water haze. If the filtered brine test procedure were revised to include filtering the Freon before IR analysis, the procedure would be more comparable to the standard IR-Oil test.

The filtered brine test is discussed more fully in Section 18. Because of apparent inconsistencies in the filtered brine test results, the data were examined only in a cursory manner in relation to brine IR-Oil content.

The filtered brine test results were consistently less than the IR-Oil test results, as would be expected, when the dispersed oil content exceeded about 15 mg/l.

Susceptibility to Separation

The purpose of the susceptibility to separation tests was to provide a quantitative measure of the rate of separation of oil from brine by gravity. Field experience demonstrated that there are significant differences in oil separation rates of different brines. As previously discussed, brine oil contents were measured after settling times from 0 to 120 minutes in separatory funnels.

Particle-Size Distribution

Small oil drops are more difficult to separate from brine than large drops. The particle-size test used provided a measure of the number of oil drops of each micron size (in the 2-120 μm range) in a calculated volume of brine. Tests were obtained on nine platforms.

The drop-size measurements were also used to calculate the concentration of dispersed oil. These calculated oil concentrations generally did not check well with oil content as measured by standard procedures. The particle-size tests are discussed in Section 16.

Infrared Scan of Freon Extracts

Infrared scans of Freon extracts were run to identify functional groups in the material measured as oil. A special interest was whether or not addition chemicals were contributing to effluent oil content.

The IR-scan tests gave a qualitative indication that carboxylic acid groups were present in the Freon extracts of the brine of the three Phase I platforms. The test did not provide a positive indication of the presence of addition chemicals. The IR-scan tests were not continued for Phase II testing.

Suspended Solids Tests

Oil coated solids are a potential contributor to brine oil content. Suspended solids tests were run to permit examining the theory that there is a correlation between brine suspended solids content and brine oil content.

As the Program progressed, it became apparent that the precision of the suspended solids test as applied in the field was limited. The apparent cause was retention of variable amounts of salt on the filters. This problem is discussed more fully in Section 18 with a study of the amount of water washing of the filters required to improve the precision of the test.

Because of the limited precision of the suspended solids test, the data was analyzed only in a cursory manner.

DATA EVALUATION AND PRESENTATION

The primary purposes of the data evaluation were to describe the effluent oil content data base provided by the survey testing and to determine which other parameters correlated with the effluent oil content. The analytical test results for each platform are presented in a separate section as follows:

Phase I

Section 6, SP65B
Section 7, WD45C
Section 8, ST177

Phase II

Section 9, BM2C
Section 10, ST131
Section 11, BDCCF5
Section 12, SS107
Section 13, SS198G
Section 14, EI18CF
Section 15, SM130B

TYPING GUIDE SHEET

The particle-size distribution test results are presented in Section 16. Comparisons between platforms are presented in Section 17.

All test results obtained during the survey, without exception, are presented in the appropriate data tables. A small number of test results were excluded from statistical analysis, but only for one of three reasons. When test results were excluded from analysis, then a footnote is always provided below that data table. This note states why that value was excluded. The three reasons for excluding data from analysis are:

1. Test results representing a system upset caused by conducting the survey were not included in the data analysis. A guideline of the program was that no changes in operations were to be made for the survey. The systems were to be evaluated as they typically operated. Twice the survey team interrupted the addition of water treating chemical. Six effluent sample periods were affected on one platform and one sample period on another. Once the operator caused a flotation unit upset in the process of installing a flow monitor for the survey. One effluent sample was affected.

2. When observation indicated a probable testing error, the result was not included. For example, salt crystals were observed in the residue after evaporation of Freon for the gravimetric oil content test of five samples during the survey.

3. A total of six effluent oil content test results were not included in the data analysis based on the subjective opinion that they were in error because of inconsistency with other test results.

The primary statistical parameters used in evaluating the data were means and standard deviations. Some linear least squares regression models were tested and some frequency distributions were plotted. The following symbols are used in presenting the data:

n = Number of samples
$\bar{x}$ = Sample arithmetic mean
s = Sample standard deviation using $(n-1)$ sample weighting
r = Linear regression correlation coefficient
$\bar{\Delta}$ = Mean difference in paired values
s_{Δ} = Standard deviation of paired values

Certain data samples were compared as paired values. The IR-Oil and GR-Oil test results were compared in this manner as well as in terms of sample means and standard deviations. The samples for the tests by the two oil content procedures were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Paired values were also used as one basis for comparing flotation unit influent and effluent oil content test results. The paired samples were taken

EPA-287 (Cin.)
(4-76)

only a few minutes apart. However, each flotation unit had a significant residence time. Time-dependent sampling differences would be important. Even so, with steady operations the paired comparisons are of interest.

In the following sections, the survey test data are displayed in tables, time-indexed plots, histograms, and linear regression plots.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

SECTION 6

PLATFORM SP65B

GENERAL

Platform SP65B was the first on which tests were conducted. A ten-day test program conforming closely with the approved program plan was started on June 13 and completed on June 22, 1979.

A detailed description of the production facilities, the test program, and data presentation and evaluation are provided in this section.

Four survey team members arrived at the platform by helicopter with a Company engineer about Noon on June 12 and were immediately given a safety briefing. Field test equipment arrived by boat about 1600 hours and was unloaded and set up, so that sampling and testing could start the following morning. Oil company personnel assisted in every possible way in unloading equipment, and providing work space, sample taps, utilities and living quarters.

There were no disruptions of the test program during the ten days caused by weather or operational problems.

FACILITIES AND OPERATIONS

Production From Wells

At the time of the survey, 30 wells were producing an average of 1,218 m^3/d (7,658 bpd) of crude oil, 643 m^3/d (4,045 bpd) of water, and 329,270 std m^3/d (11,635 Mcfd) of gas. These averages are based on well test data.

Two wells producing 69 m^3/d (432 bpd) of oil but no water flowed by reservoir pressure to a medium-pressure two-phase separator. The oil flowed from the medium-pressure separator to a low-pressure manifold. Six wells producing 292 m^3/d (1,835 bpd) of oil and 1.1 m^3/d (7 bpd) of water flowed by reservoir pressure to the low-pressure three-phase separator. Production from 22 wells producing 857 m^3/d (5,391 bpd) of oil, and 642 m^3/d (4,038 bpd) of water was gas lifted to the low-pressure separator.

Combined flow to the low-pressure separator of 1,218 m^3/d (7,658 bpd) of oil and 643 m^3/d (4,045 bpd) of water was equivalent to a water cut of 35 percent.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Seventy percent of the oil was gas lifted, and 99.8 percent of the water was gas lifted.

Measured production for the ten-day period averaged 1,184 m^3/d (7,447 bpd) or 2.8 percent less than was indicated by well test data.

Chemicals are not used downhole on SP65B. Also, no well work over operations were conducted during or shortly before the survey that would affect the characteristics of the produced fluids.

Production Process System

The flow of oil and water through the system is shown in Figure 3. Design and operating data on major vessels are presented in Table 10. The primary oil/water flow is to the low-pressure three-phase separator, also called a free water knock out (FWKO). Five to six percent of the oil flows through a two-phase medium-pressure gas separator before entering the low-pressure separator.

About 99 percent of the water drops out in the free water knock out. The oil flows to the electrostatic oil treater where the water content is reduced to less than 0.5 percent. The crude oil then flows to a storage tank to be pumped to a pipeline for sale.

A demulsifier, Nalco 4400, is added continuously at the rate of 11 dm^3/d to the low-pressure manifold. A biocide, Champion DQ61, is added continuously at the rate of 4 dm^3/d also to the low-pressure manifold.

The purpose of the facilities discussed to this point is the production of saleable crude oil and gas.

Figure 4 is a flow schematic for the water handling system. The purpose of this system is to prevent the loss of oil from the platform and to treat oily water to a satisfactory level for discharge. A nominal average water flow balance is presented in the figure. Some of the flows are estimates. More detailed flow and flow-variability data are presented in a following subsection.

The primary produced water flow is from the free water knockout to the skim tank (gravity separator), to the flotation unit, and then to discharge. Other water flows to the skim tank are from the oil treater, from a closed sump receiving flotation froth and miscellaneous drains, and from the skim pile.

All oily water flows, or is pumped to the skim tank for gravity separation of oil. The major continuous flow is from the free water knock out. There are also continuous flows from the oil treater, and the froth flow from the flotation unit.

Drains from most potentially oil contaminated areas flow to the closed sumps. The two pumps in the closed sumps operate on level control, but one pump runs continuously.

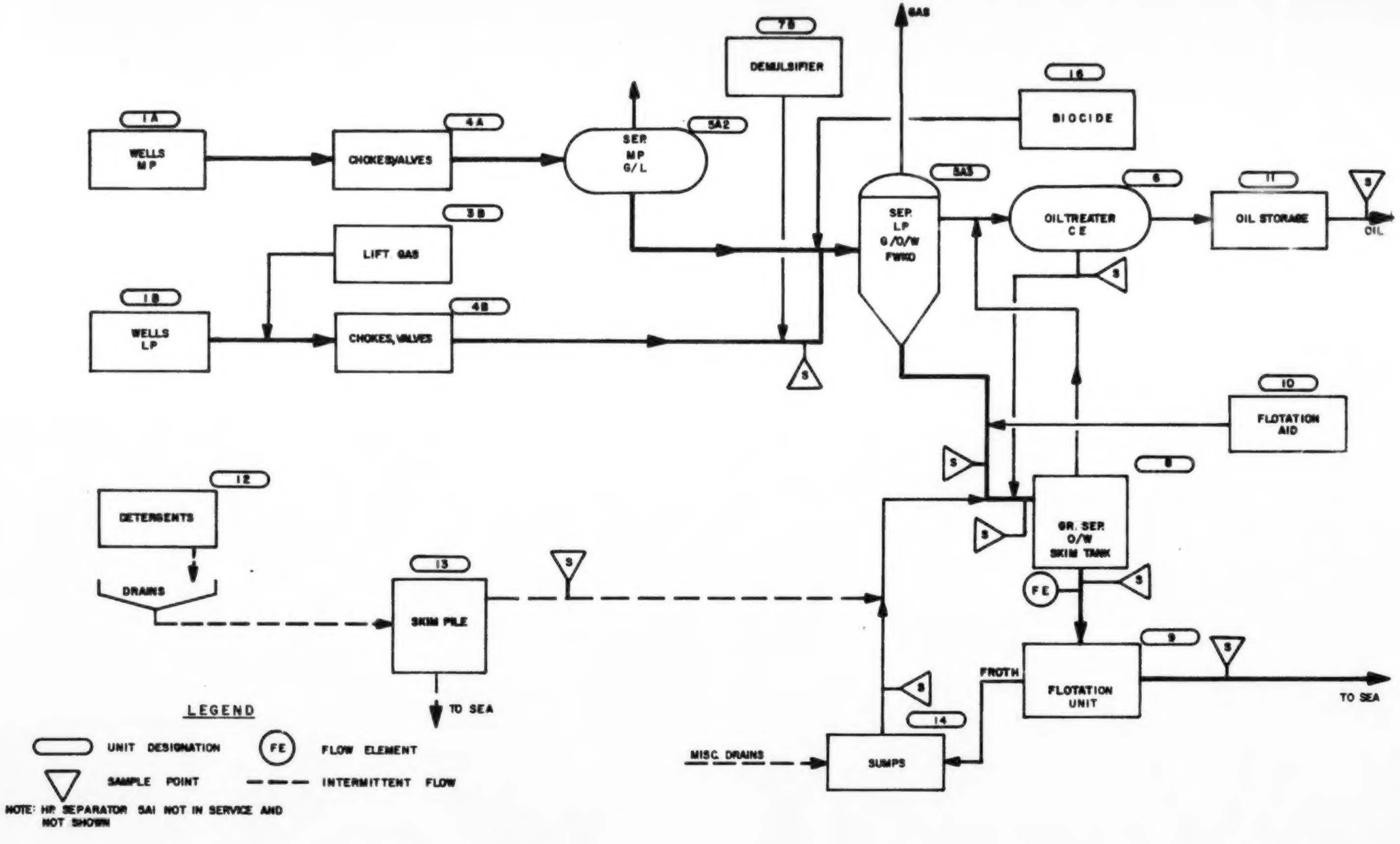
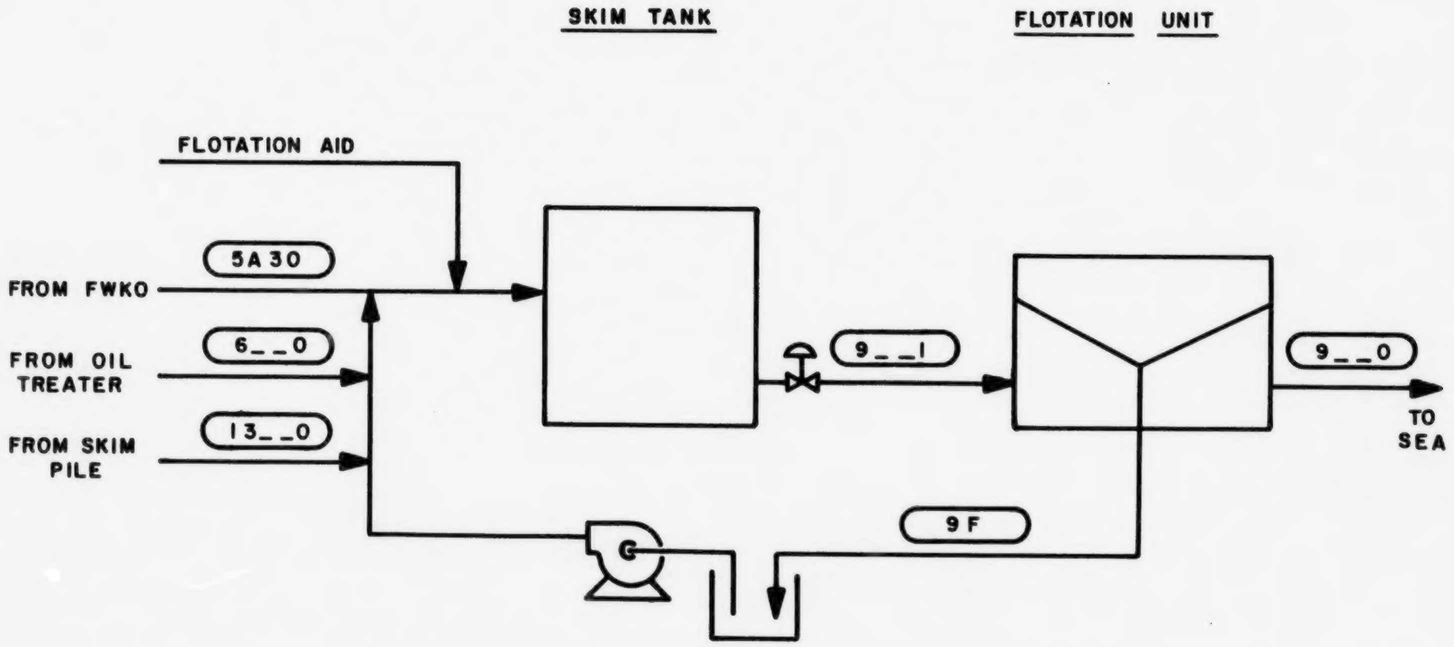

1A
WELLS MP
4A
CHOKES/VALVES
5A2
SEP. MP G/L
3B
LIFT GAS
1B
WELLS LP
4B
CHOKES, VALVES
7B
DEMULSIFIER
GAS
16
BIOCIDE
5A3
SEP. LP G/O/W FWKO
6
OIL TREATER CE
11
OIL STORAGE
S
OIL
10
FLOTATION AID
8
GR. SEP. O/W SKIM TANK
FE
9
FLOTATION UNIT
FROTH
TO SEA
12
DETERGENTS
DRAINS
13
SKIM PILE
TO SEA
14
SUMPS
MISC. DRAINS
LEGEND
UNIT DESIGNATION
FLOW ELEMENT
SAMPLE POINT
INTERMITTENT FLOW
NOTE: HP. SEPARATOR 5A1 NOT IN SERVICE AND NOT SHOWN

Figure 3. Flow diagram, production process system, SP65B.

TABLE 10. SP65B Vessel Data Sheet

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 6-1				
	5A2 Medium pressure gas/liquid separator	5A3 Low pressure 3-phase separator	6 Oil treater, chem electric	8 Gravity separator, skim tank	9 Flotation unit, mechanical, dispersed gas
Trade Name or Vessel Type	Horizontal Cylinder	Vertical Cylinder Cone-Bottom	Horizontal Cylinder	Rectangular Tank	Wemco Model 84
Design Parameters					
Dimensions, m, (ft)(1)					
Diameter, O.D.	-	4.27(14)	3.66(12)	-	-
Length, S.S.	-	-	10.67(35)	-	-
Length	-	-	-	11.43(37.5)	6.92(22.7)
Width	-	-	-	3.96(13)	1.86(6.1)
Height	-	-	-	9.14(30)	-
Surface Area, m^2, (ft^2)					
Separation Total	-	14.3 (154)	-	45.3 (488)	12.91(139)
Per Cell	-	14.3 (154)	-	45.3 (488)	3.25(35)
Separation Volume, m^3, (bbl)					
Total	-	-	-	-	17(107)
Oil Phase	-	6.5 (41)	-	-	-
Water Phase	-	33.4 (210)	7.3 (46)	328(2,064)	-
Number of Cells	-	-	-	-	4
Flow Rate, m^3/day, (bpd)(2)	-	-	-	-	6,135(38,585)
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)(3)	-	-	-	-	1,888(1,102)
Recycle Rate, Percent of Flow	-	-	-	-	-
Retention Time, min.	-	-	-	-	4
Average Operating Parameters					
Temperature, $^{\circ}$C($^{\circ}$F)	-	40(104)	40(104)	38(100)	39(102)
Pressure, kPag, (psig)	4,206(610)	593(86)	207(30)	0(0)	0(0)
Flow Rate, m^3/d (bpd)(2)	-	637(4,005)	6.4 (40)	955(6,006)	655(4,120)
Flow Rate, Percent of Design	-	-	-	-	11
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)	-	45(26)	-	21(12.3)	202(118)
Recycle Rate, Percent of Flow	-	-	-	-	-
Froth Flow, Percent of Flow	-	-	-	-	46

(1) Tank dimension only.
(2) Water flow rate.
(3) Overflow rate is surface area divided by flow rate.


SKIM TANK
FLOTATION UNIT
FLOTATION AID
5A30
FROM FWKO
6__0
FROM OIL TREATER
13__0
FROM SKIM PILE
9__1
9__0
TO SEA
9F

WATER FLOW		5A30	6__0	13__0	9F	9__1	9__0
	m^3/d	637	6	12	300	955	655
	bpd	4005	40	75	1886	6006	4120

Figure 4. SP65B water handling system flow schematic.

TYPING GUIDE SHEET

The skim pile receives drainage intermittently from areas that may be oil contaminated. Curbed areas flow to the skim pile during rains. It did not rain during the test period. Sand collected in the bottom of the skim tank is also drained to the skim pile. Water or oil is pumped from the skim pile by a gas lift pump. The pump operates on a timer, 6 seconds out of every 55 seconds or about 11 percent of the time. The flow rate is estimated at 12 m^3/d. Oil was not observed to be present in the water returned from the skim pile during the ten-day test period.

A water treating chemical, Nalco 8AF542, is added continuously to the skim tank influent at the rate of 11 dm^3/d. This system is unique in that the coagulant chemical which enhances the flotation process is added ahead of the gravity separator rather than just ahead of the flotation unit.

The skim tank is a large rectangular vessel. Figure 5 is a dimensional sketch of the skim tank and also shows probable flow patterns. Water enters the tank at a depth of 6.6 m through two inlet distribution pipes extending the width of the tank. Water flows through evenly spaced 1.9 cm x 3.8 cm holes on each side of the pipes. The inlet distributors function to disperse the water uniformly in the upper part of the tank and develop a laminar, non-turbulent downflow in the primary gravity separation zone of the tank. Three outlets are located at 1.2 m depth, 5.3 m below the inlets.

At an average flow rate of 955 m^3/d (6,006 bpd), the average holding time is 8.2 hours. The average flow rate in terms of surface area is 21 $(m^3/d)/m^2$ (12.3 bpd/ft^2).

The skim tank is a well designed gravity separator. It is conservatively sized for the flow it receives. The actual performance is compared to expected performance in a later section of this report.

The skim tank has sloped bottom sections to permit draining accumulated sand. Drain details are not shown on the drawing. Oil drain details also are not shown.

The polishing unit is a proprietary four-cell dispersed gas flotation unit (Wemco 1 + 1, Model 84) as shown in Figure 6. Gas dispersion is by mechanical eduction. Oil separation is by skimming a froth over side weirs in each section. The rated flow is 6,135 m^3/d (38,585 bpd) with a holding time in each cell of one minute. The manufacturer recommends this unit for especially difficult oil/water separation jobs. The unit operates with a gas blanket to exclude air.

The average effluent flow from the unit was 655 m^3/d (4,120 bpd) or only about 11 percent of the design flow. The unit operated with froth overflow in the range from 17 to 86 percent of the effluent flow. This is higher than a normal froth overflow of about 5 percent but should contribute rather than detract with respect to effective oil separation.

A general conclusion is that the combined skim tank-flotation system is conservatively designed.

EPA-287 (Cin.)
(4-76)

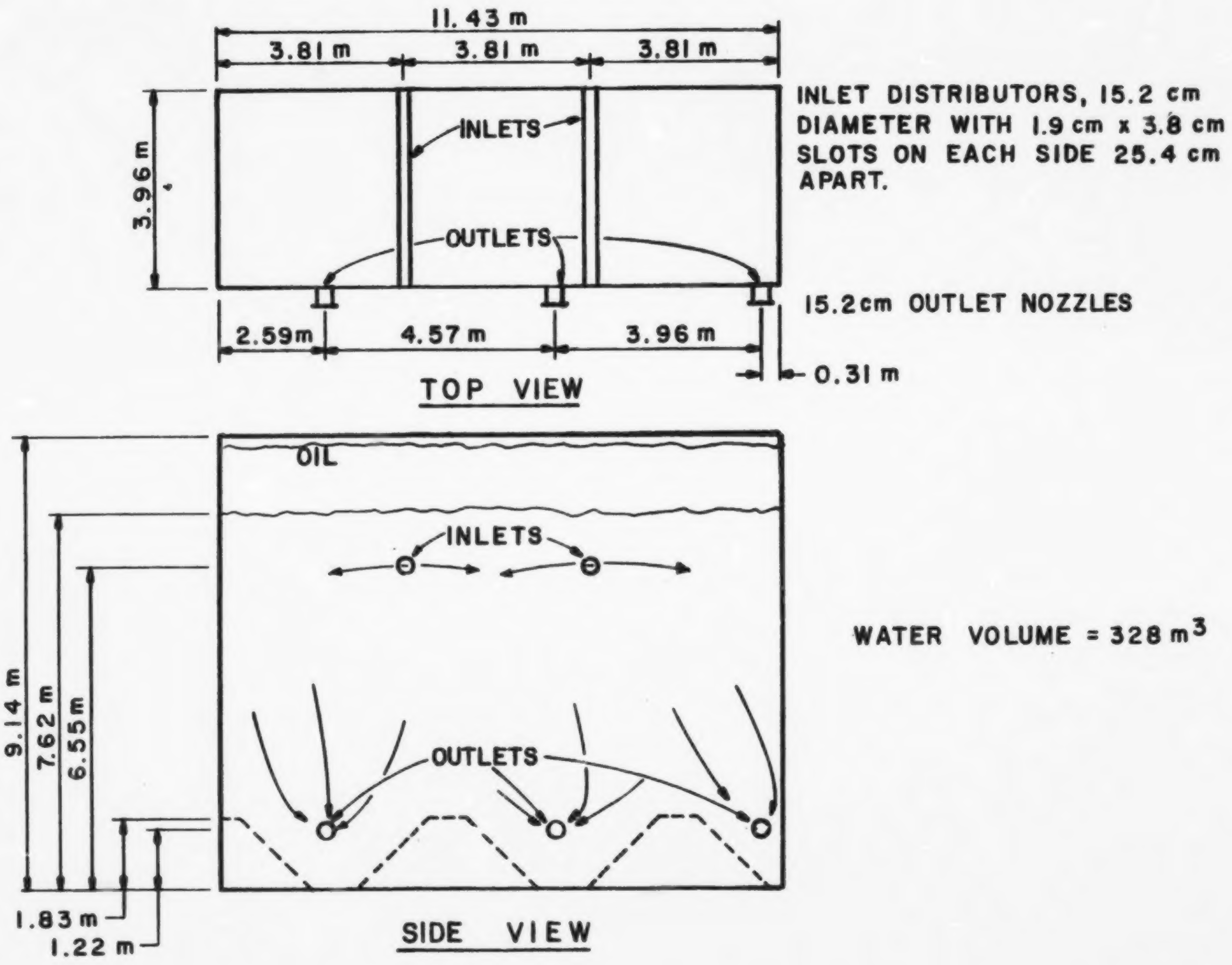

11.43 m
3.81 m
3.81 m
3.81 m
3.96 m
INLETS
OUTLETS
INLET DISTRIBUTORS, 15.2 cm DIAMETER WITH 1.9 cm x 3.8 cm SLOTS ON EACH SIDE 25.4 cm APART.
15.2cm OUTLET NOZZLES
2.59m
4.57 m
3.96 m
0.31 m
TOP VIEW
OIL
INLETS
WATER VOLUME = 328 m³
9.14 m
7.62 m
6.55 m
OUTLETS
1.83 m
1.22 m
SIDE VIEW

Figure 5. SP65B skim tank sketch.

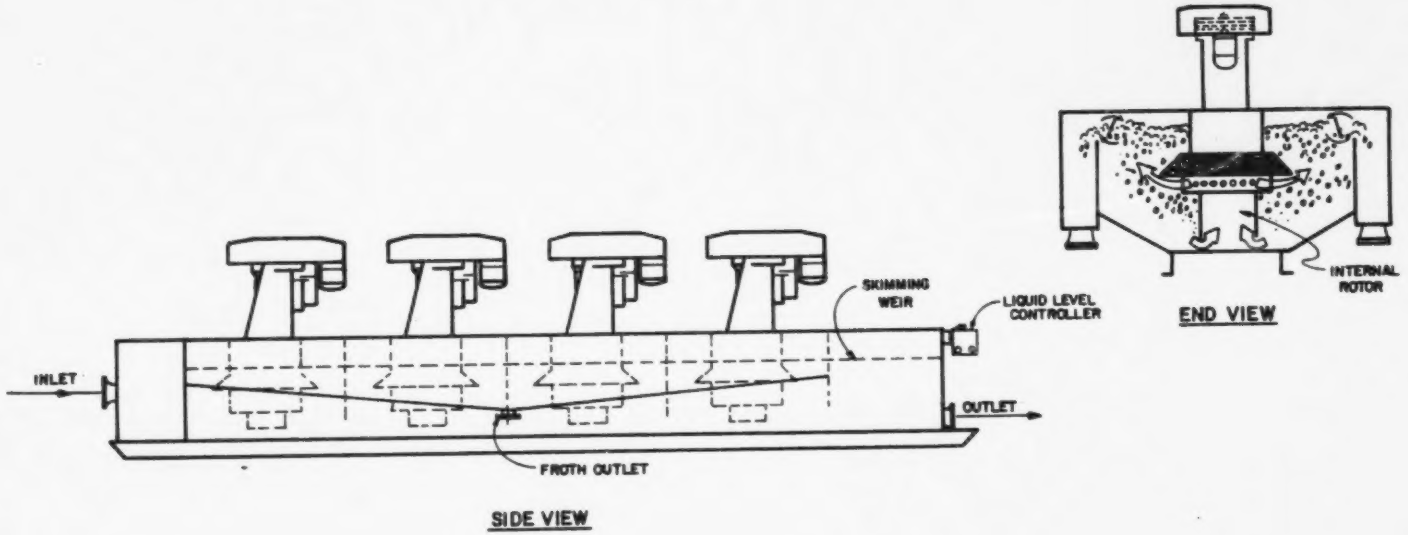

SKIMMING WEIR
LIQUID LEVEL CONTROLLER
INLET
OUTLET
FROTH OUTLET
SIDE VIEW
INTERNAL ROTOR
END VIEW

Figure 6. SP65B flotation unit sketch.

SITE SPECIFIC TEST PROGRAM

The planned test program for major brine samples is presented in Table 11. The number of samples to be taken in ten days and the time the samples are to be taken each day are listed. The listed program was carried out with only minor variations as will be observed later. A limited number of tests were run at minor sampling points not shown in Table 11.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

Particle size distribution measurements were not obtained on SP65B. Field application equipment problems, and limited operator experience were the reasons.

OPERATIONAL DATA AND OBSERVATIONS

The types of data to be collected and the purposes were discussed in general terms in Section 5. Measurements, records, and observations for the ten-day survey period on SP65B are reported in this subsection.

Flow Monitoring

A major effort was made to obtain a continuous record of flow of the polishing unit effluent, by use of the clamp-on ultrasonic monitor purchased for this purpose. All efforts failed. The monitor had been checked out onshore. The manufacturer's service representative worked with the unit on the platform, and could not tell whether it was an equipment problem or an application problem.

On the seventh day of the test program, an orifice plate flow meter with recorder was placed in service on the skim tank outlet, which is also the flotation unit inlet. Three days of hourly average, minimum, and maximum flow are charted in Figure 7.

The hour-to-hour flow rates are relatively uniform, and the average daily rates are very uniform. However, differences in hourly minimums and maximums are wide compared to average flows.

In considering short-term flow variability, it should be noted that the flow is controlled by a dump valve. The dump valve operates from a high level sensor in the skim tank. Flow was fluctuating on one-minute cycles over a 110 to 160 m^3/d range. For example, if the average one-minute flow was 820 m^3/d, the range could be from 740 to 900 m^3/d. Further, a 110 m^3/d difference in average flow from one 15-minute period to the next was not uncommon.

The flotation unit effluent flow rate can be calculated by subtracting the froth recycle flow from the influent flow.

The froth flow rate was calculated from the time required to fill a known

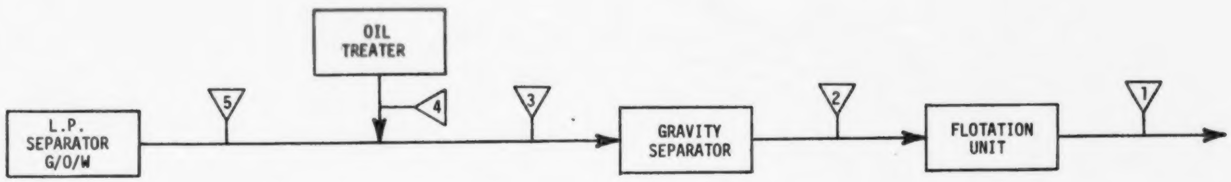


TABLE 11. SP65B TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS									
	1		2		3		4		5	
	9--0		9--i		8--i		6--0		5A30	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests										
Infrared Oil	40	8,10,13,15	40	8,10,13,15	20	8,13	20	8,13	20	13
Temperature	20	8,10	10	10	10	10	10	10	10	10
pH	10	10	-	-	-	-	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-	-	-	-	-
Water Surface Tension	10	8	-	-	-	-	-	-	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	-	-	-	-	-	-
IR-Oil Filtered Brine	10	8	-	-	-	-	-	-	-	-
Susceptibility to Separation	-	-	-	-	-	-	-	-	2	(1)
Laboratory Tests										
Gravimetric Oil	40	8,10,13,15	20	8,13	-	-	-	-	20	8,13
Suspended Solids	10	15	10	15	10	15	-	-	2	15
Ionic Analysis	1	(1)	-	-	-	-	-	-	-	-
Bacterial Culture	1	(1)	1	(1)	-	-	1	(1)	1	(1)
Particle Size Distribution	3	(1)	3	(1)	3	(1)	-	-	-	-
IR-Scan of Freon Extracts	1	-	-	-	-	-	-	-	-	-

(1) Field scheduled.

NOTE: Some of the one-a-day samples were not scheduled for a certain hour and are listed at the time actually run. Time of tests listed is by military hour.

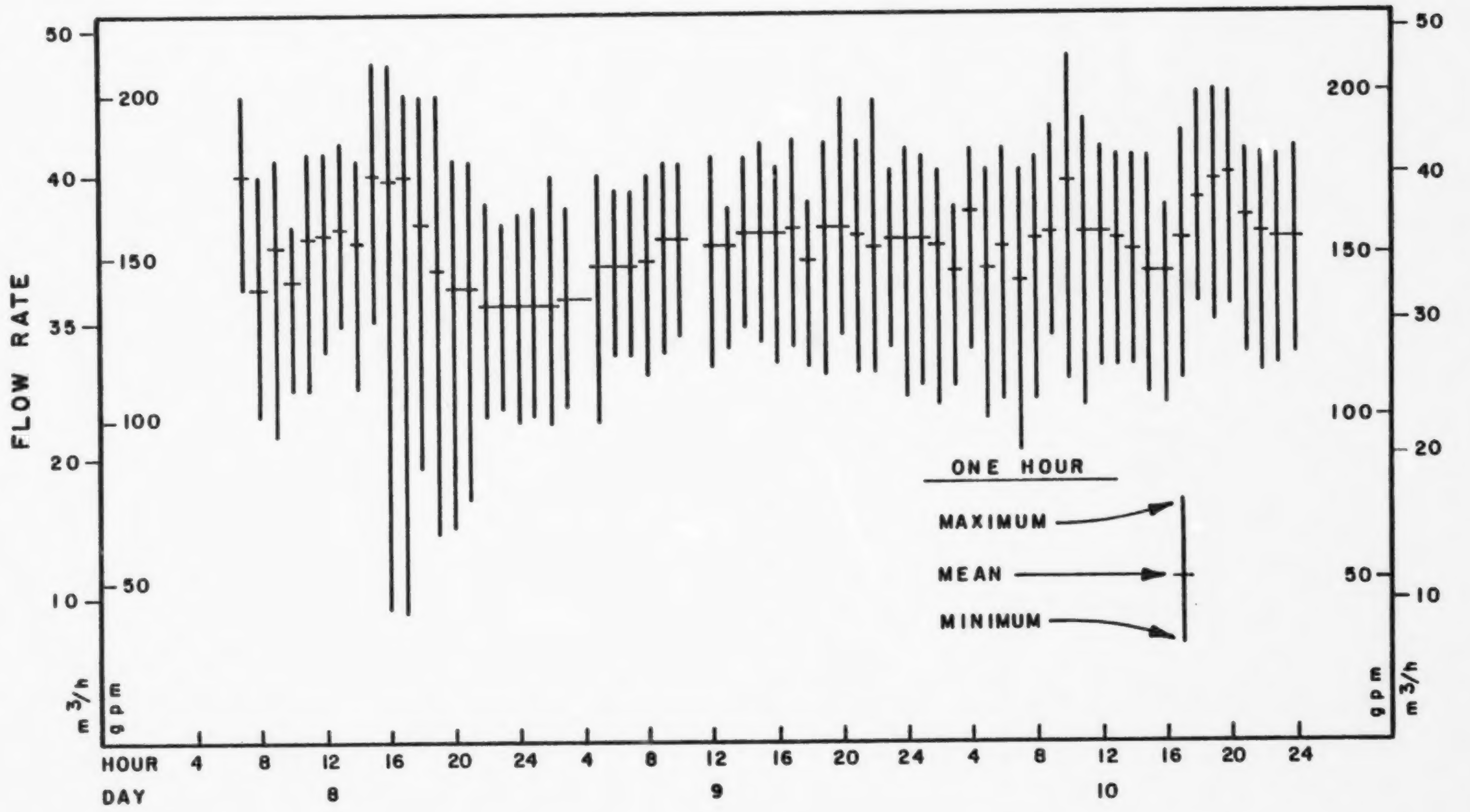


Figure 7. Flow chart SP65B skim tank effluent.

volume of the froth overflow launder when the drain valve was closed at least twice per day.

Table 12 shows calculated flotation unit effluent flows:

TABLE 12. SP65B AVERAGE WATER FLOW DATA

	24-hour average flow m^3/d (gpm)		
Day	Skim tank effluent	Froth	Flotation effluent
08	834(153)	136(25)	698(128)
09	845(155)	169(31)	676(124)
10	850(156)	202(37)	649(119)
Mean	844(155)	170(31)	674(124)

The three-day average effluent flow rate of 674 m^3/d includes an estimated 12 m^3/d from the skim pile. The produced water flow was 643 m^3/d estimated from well test data.

The three-day average froth flow of 170 m^3/d is below the overall average for the survey. The range of all froth flow rate measurements was 109 to 564 m^3/d and the average was 300 m^3/d.

Well Test Data

Production tests were run on each of the 30 producing wells either during or shortly before the survey test period. The test data as provided by the operator are presented in Table 13.

The well test data table includes:

- Well number
- Formation
- Total vertical depth
- Gas production rate
- Oil production rate
- Water production rate
- Lift gas rate
- Shut in bottom hole pressure
- Flowing tubing pressure
- Choke size
- Oil gravity

The well data are separated in the table according to lift method, and also according to which separator received the production from each well. The well test data were used in developing the average oil and water production rates and water balance previously presented.

All 30 wells flowed continuously during the ten-day survey period. The close check between oil production calculated from test data and measured oil production, 1,218 m^3/d (7,658 bpd) and 1,184 m^3/d (7,447 bpd), respectively

TABLE 13. SP65B WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig		Choke size 1/64 in.	API gravity
							SIBHP	FTP		
Flowing to Medium Pressure Separator										
B-41	G1RB	7,254	217	192	0	0	2,461	800	14	30.0
B14A	G3RA	7,317	1,062	240	0	0	2,001	800	19	28.9
Total (Average)		-	1,279	432	0	0	-	-	-	(29.5)
Flowing to Low Pressure Separator										
B-7-	G1RA	-	336	317	0	0	2,604	480	16	31.5
B-7D	G-RA	7,240	317	326	0	0	-	500	14	31.5
B-8-	H4RB	7,361	474	136	0	0	-	240	22	28.4
B20-	G1RA	7,253	1,303	238	0	0	2,604	900	20	29.6
B-21	G1RA	7,253	558	610	0	0	2,604	500	26	29.4
B27-	G1RG	7,308	2,258	208	7	0	1,493	250	48	28.6
Total (Average)			5,246	1,835	7	0	-	-	-	(29.8)
Gas Lift to Low Pressure Separator										
B-1-	G3RA	7,273	330	738	7	125	2,001	300	29	29.0
B-2-	G3RB	7,156	299	218	158	622	1,986	140	64	29.3
B-2A	G2RC	7,115	160	95	154	530	2,442	130	44	29.3
B-3A	H4RB	7,353	384	445	0	387	-	180	56	30.6
B10-	H-RC	7,205	171	69	0	250	-	110	64	34.3
B11-	G3RA	7,330	39	92	39	403	2,001	110	56	29.6
B12-	G3RD	7,420	207	353	431	553	2,638	150	56	30.5
B15-	G2RB	7,450	335	75	111	335	2,292	350	27	28.3
B15D	G1RB	7,300	105	330	177	454	2,461	150	46	28.5
B17D	G1RA	7,237	654	651	7	130	2,604	700	25	29.6
B18-	G3RA	7,294	202	404	0	357	2,150	300	26	29.3
B19D	G2RA	7,313	117	287	123	339	2,001	110	54	29.6
B22D	G2RE	7,130	537	348	0	258	1,414	250	30	30.2
B23-	G1RA	7,302	145	239	80	539	2,604	200	38	28.9
B23D	G1RA	7,255	116	303	130	220	2,604	450	19	29.6
B25-	G3RA	7,295	319	68	609	412	2,001	120	54	28.6
B25D	G2RA	-	142	102	409	369	2,001	110	50	28.6
B26-	G-RF	7,285	78	78	6	97	1,797	100	56	27.4
B28-	G1RG	7,185	227	37	0	132	1,493	120	56	28.5
B30A	G1RC	7,160	112	149	596	351	2,440	120	56	28.6
B31E	G1RB	7,320	71	121	224	651	2,461	140	56	30.5
B33D	H-RD	7,440	360	194	777	460	-	250	44	29.4
Total (Average)		5,110	5,110	5,391	4,038	7,974	-	-	-	(29.5)
Combined Total (Average)		-	11,635	7,658	4,045	7,974	-	-	-	(29.5)

lends credibility to water production estimates based on the test data.

Vessel Pressures and Temperatures

The pressure of each oil/water separation vessel was recorded twice per day. The temperature was recorded once per day based on the temperature of an effluent sample.

Table 14 presents pressure and temperature ranges for the ten-day period.

TABLE 14. SP65B VESSEL TEMPERATURES AND PRESSURES

Vessel	Pressure, kPag (psig)	Temperature, °C
Medium Pressure Separator	4,140-4,240 (600-615)	-
Low Pressure Separator	580-610 (84-88)	37.7-40.5
Oil Treater	200-214 (29-31)	36.5-41.8
Skim Tank	0 (0)	35.4-39.6
Flotation Unit	0 (0)	35.5-39.8

Table 14 indicates steady operation of all vessels in narrow temperature and pressure ranges for the ten-day period.

Pressure Drops Through System

Table 15 traces pressure drops from the producing formation through the system.

Table 15 shows that the greatest pressure drops occur from the formation to the chokes, substantial drops occur at the chokes, and more minor drops from the chokes on. The data in Table 15 includes only the wells producing water.

The pressure drop data are tabulated to permit evaluation of the theory that pressure drops at chokes and valves may form small-particle oil dispersions that are difficult to remove in separation equipment.

TABLE 15. SP65B PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Formation (SIBHP)	10,290-18,190 (1,493-2,638)		
		perforations, static head, pipes	8,570-17,150 (1,243-2,488)
Flowing Tubing Pressure	690-4,830 (100-700)		
		chokes, valves, pipes	100-4,240 (15-615)
Low Pressure Separator	580-610 (84-88)		
		control valve, pipes	580-610 (84-88)
Skim Tank	0		

Chemical Addition

Three chemicals were added continuously by small metering pumps as listed below in Table 16.

The water treating chemical was added ahead of the skim tank and may have enhanced both gravity separation and flotation of oil.

TABLE 16. SP65B CHEMICAL ADDITION

Chemical	Addition point	Addition rate	
		dm^3/d	ppmv
Champion DQ 61 (Biocide)	Low pressure separator inlet manifold	4	6(1)
Nalco 4400 (Demulsifier)	Low pressure separator inlet manifold	11	17(1)
Nalco 8AF542 (Water treating chemical)	Low pressure separator outlet	11	17(1)

(1) Based on average volume of water discharged from the flotation unit.

The chemical feed rates were checked twice per day by observing the pump down rate in a gauge glass for one minute. This is not a highly precise measurement but does confirm that the chemicals were being added at approximately the intended rate.

The chemicals were added uniformly and continuously, except that the feed pump for the water treating chemical was not functioning when sampling started at 0800 hours on the first day. The problem was malfunction of a check valve. The pump was repaired and put in service at 1600 hours on the first day and functioned for the rest of the ten-day period.

Observations and Operator Reports

An effort was made to record any event that could affect effluent oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures, and the survey team made their own observations.

All 30 wells produced continuously for the ten days. Most of the wells were diverted to the test separator for a few hours but the fluids were dumped to the low-pressure separator as they would have been during normal production. There were no major upsets.

The following are comments on observations and non-routine events.

The flotation unit was opened and inspected from two to several times each day. In every case, there was a good froth layer which was being skimmed effectively.

The water from the skim pile was regularly inspected and was never observed to contain oil. On Days 8, 9 and 10, the skim pile water had an anerobic sulfide-type odor and hazy appearance. It was suspected that draining sand from the skim tank may have seeded the skim pile.

On Day 1, the water treating chemical feed pump was not functioning as previously noted. The effect is discussed in the data presentation section.

On Day 1 and Day 2, the oil content in the skim tank inlet was high. Any of the four makeup streams--the freewater knock out, the oil treater, the closed sump, or the skim pile--could have been the source, but the actual source was not identified.

On Days 2, 3 and 10, intermittent water-level-control fluctuations were experienced with the oil treater. This could result in discharging high oil content water to the skim tank, but analytical tests did not confirm a problem.

On Day 8, one of the two sump pumps was taken out for repairs. The other pump was adequate to handle the full flow.

Detergents were not used for washdown during the survey.

There was no flow contribution by rainfall during the survey.

In general, operations were uniform with respect to factors that would be expected to change the quality of the water discharged.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables and summary tables and graphs are interspersed in the text.

Effluent Oil Content

Table 17 presents a listing of all oil content test results. Figure 8 presents a plot of GR-Oil content in and out of the flotation unit versus time for the ten-day period. Figure 9 presents the same plot for IR-Oil content.

The graphs show an erratic pattern of higher oil content values for the first six samples taken, four the first day and two the second day. The test values for the remaining eight and one-half days are in a narrow range at a lower concentration. The flotation aid chemical was not being added most of the first day and several hours were required to establish effective oil separation after chemical addition was restarted. The flotation influent and gravity separator influent oil content values were also comparatively high during the same period. The reason was not determined. The high effluent oil content values on Day 1 and Day 2 appeared to be caused by loss of chemical addition and other undetermined factors.

The ranges of test results are as follows:

Flotation Effluent GR-Oil - 39 to 552 mg/l,
Flotation Effluent IR-Oil - 57 to 448 mg/l,
Flotation Influent GR-Oil - 70 to 482 mg/l,
Flotation Influent IR-Oil - 91 to 692 mg/l.

Flotation unit effluent oil content histograms for the two test methods are presented in Figure 10 and Figure 11. Figure 12 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Table 18 presents a summary comparison of test results by the two methods.

As expected, the mean by the IR-Oil method is higher. Only one GR-Oil test result exceeded the paired IR-Oil result. The substantial standard deviation for paired tests indicates that there is not a uniform difference in paired tests.

TABLE 17. SP65B MAJOR BRINE TESTS

Sample time		LP separator effluent (5A30)		Oil treater effluent (6--0)	Grav. separator influent (8--i)	Flotation unit influent (9--i)		Flotation unit effluent (9--0)							
										IR-Oil w/silica gel		Filtered brine	Surface tension	Flow rate	
Day	Hour	GR-Oil mg/l	IR-Oil mg/l	IR-Oil mg/l	IR-Oil mg/l	GR-Oil mg/l	IR-Oil mg/l	GR-Oil mg/l	IR-Oil mg/l	Dispersed mg/l	Soluble mg/l	IR-Oil mg/l	dynes/cm	Out(2) m^3/d	Skimmings m^3/d
01	08(1)	1,354	1,544	457	96,000	482	631	183	270	191	79	57	43	655	-
01	10(1)	-	-	-	-	-	692	294	374	-	-	-	-	655	-
01	13(1)	-	1,044	174	52,188	441	578	390	448	331	117	-	-	655	-
01	15(1)	-	-	-	-	-	400	224	300	-	-	-	-	655	-
02	08	575	-	774	23,920	124	370	50	66	12	54	43	68	655	-
02	10	-	-	-	-	-	144	48	391	-	-	-	-	655	-
02	13	659	905	165	82,631	93	122	54	63	7	56	-	-	655	-
02	15	-	-	-	-	-	117	57	62	-	-	-	-	655	-
03	08	936	1,131	1,783	1,131	111	122	85	70	6	64	152	71	655	-
03	10	-	-	-	-	-	126	52	66	-	-	-	-	655	-
03	13	859	922	261	565	113	130	50	67	5	62	-	-	655	-
03	15	-	-	-	-	-	139	49	70	-	-	-	-	655	-
04	08	652	1,022	483	839	109	135	57	70	7	63	71	73	655	564
04	10	-	-	-	-	-	122	58	70	-	-	-	-	655	564
04	13	922	1,131	174	922	106	126	53	73	9	64	-	-	655	564
04	15	-	-	-	-	-	126	63	73	-	-	-	-	655	564
05	08	566	739	217	1,566	91	113	63	73	16	57	69	66	655	202
05	10	-	-	-	-	-	104	57	66	-	-	-	-	655	202
05	13	559	739	2,435	1,218	93	113	70	81	21	60	-	-	655	365
05	15	-	-	-	-	-	113	56	66	-	-	-	-	655	365
06	08	631	705	296	774	99	104	52	58	7	51	64	72	655	409
06	10	-	-	-	-	-	104	43	59	-	-	-	-	655	409
06	13	534	635	226	957	119	96	48	57	10	47	-	-	655	447
06	15	-	-	-	-	-	130	46	63	-	-	-	-	655	447
07	08	876	979	418	778	92	104	47	63	9	54	70	72	655	262
07	10	-	-	-	-	-	113	44	64	-	-	-	-	655	262
07	13	828	765	187	2,392	91	139	59	67	12	55	-	-	655	332
07	15	-	-	-	-	-	113	49	64	-	-	-	-	655	332
08	08	553	600	348	739	113	122	67	77	19	58	65	70	655	109
08	10	-	-	-	-	-	113	52	81	-	-	-	-	655	109
08	13	453	644	122	591	105	130	61	84	31	53	-	-	655	158
08	15	-	-	-	-	-	130	552(A)	86	-	-	-	-	655	158
09	08	639	644	165	2,783	70	100	45	77	22	55	62	71	655	136
09	10	-	-	-	-	-	91	53	81	-	-	-	-	655	136
09	13	426	652	413	2,653	89	104	519(A)	76	20	56	-	-	655	202
09	15	-	-	-	-	-	113	45	80	-	-	-	-	655	202
10	08	422	522	404	3,131	78	104	52	70	14	56	75	65	655	202
10	10	-	-	-	-	-	144	42	76	-	-	-	-	655	202
10	13	533	744	374	2,870	72	100	61	75	18	57	-	-	655	202
10	15	-	-	-	-	-	109	39	71	-	-	-	-	655	202
Minimum		422	522	122	565	70	91	39	57	5	47	43	43	-	109
Maximum		1,354	1,544	2,435	96,000	482	692	552	448	331	117	152	73	-	564

(1) The flotation chemical feed pump was running, but was not pumping. Test results are included in data analysis.
(2) Based on well test data.
(A) Not included in data analysis. Appears inconsistent with other GR-Oil, IR-Oil, and "soluble" oil tests.

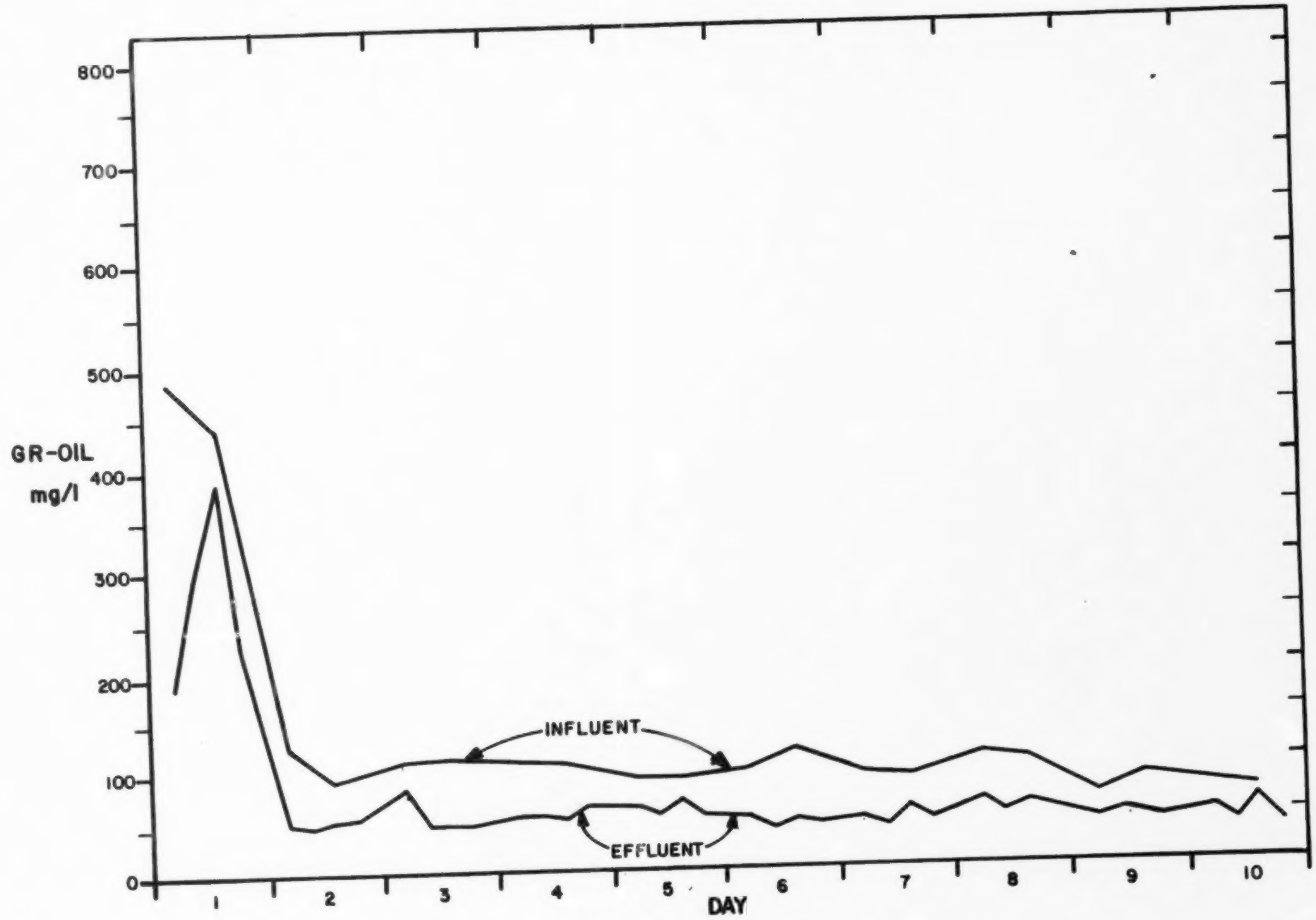


Figure 8. SP65B flotation unit performance, GR-oil vs time.

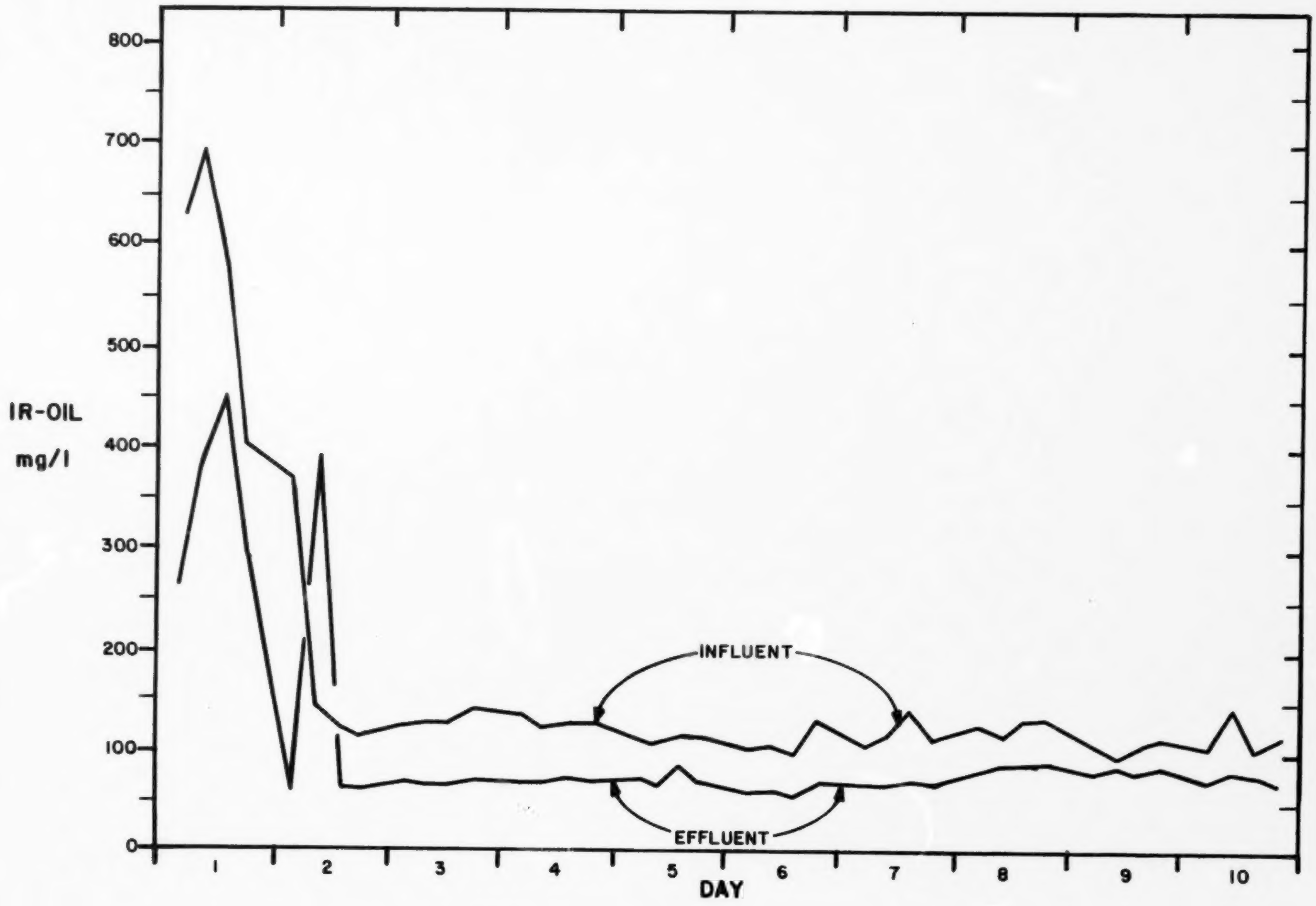


Figure 9. SP65B flotation unit performance, IR-oil vs time.

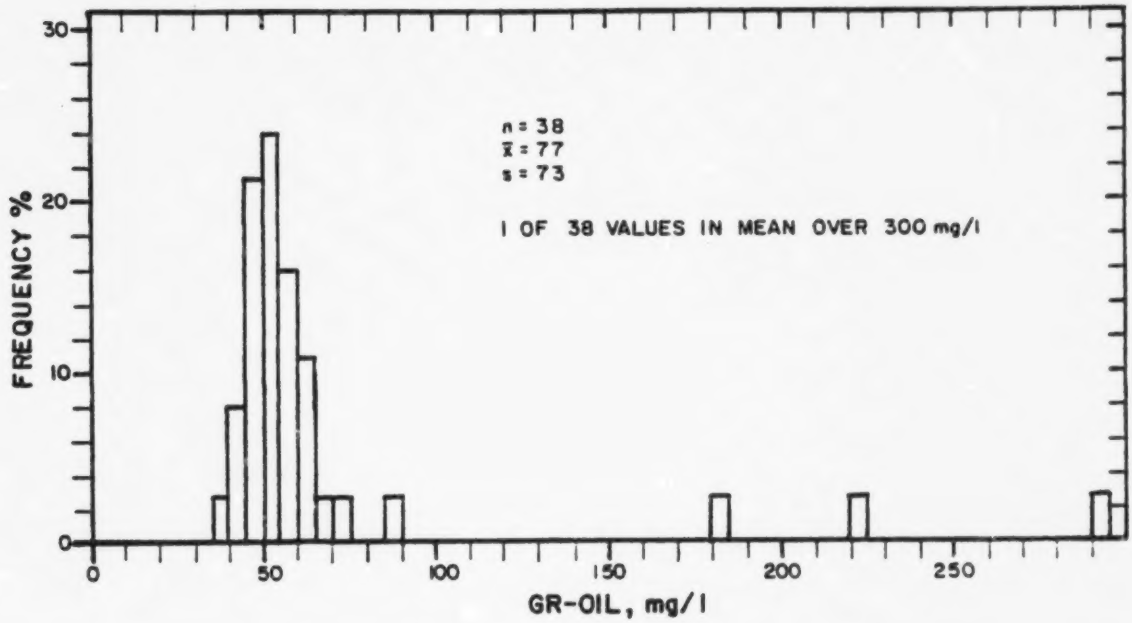


Figure 10. SP65B flotation unit effluent, GR-oil histogram.

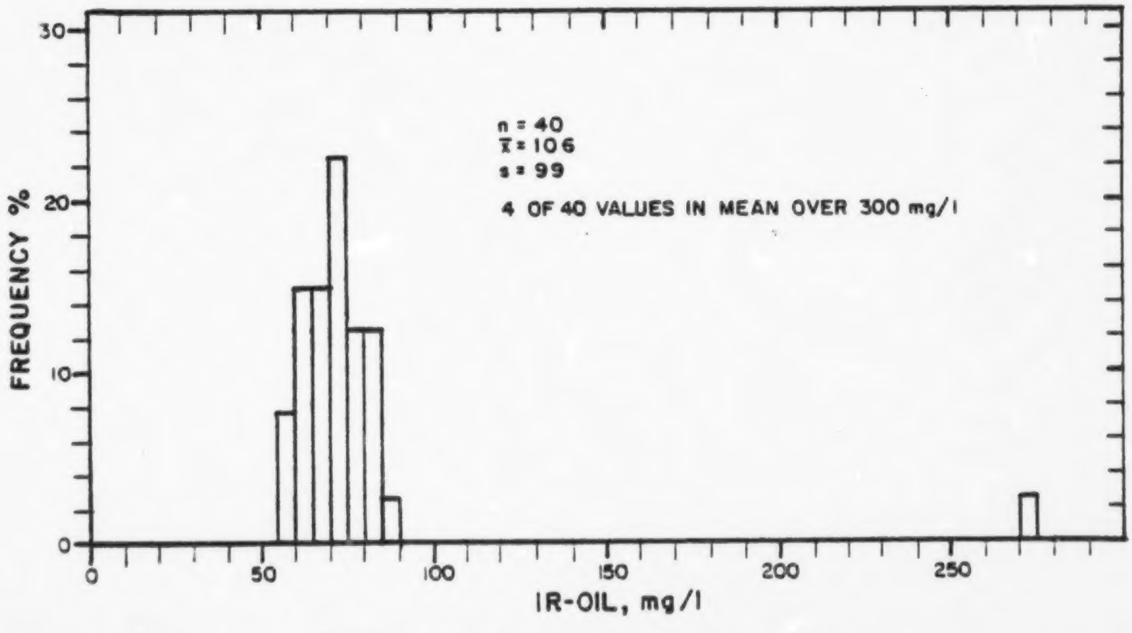


Figure 11. SP65B flotation unit effluent, IR-oil histogram.

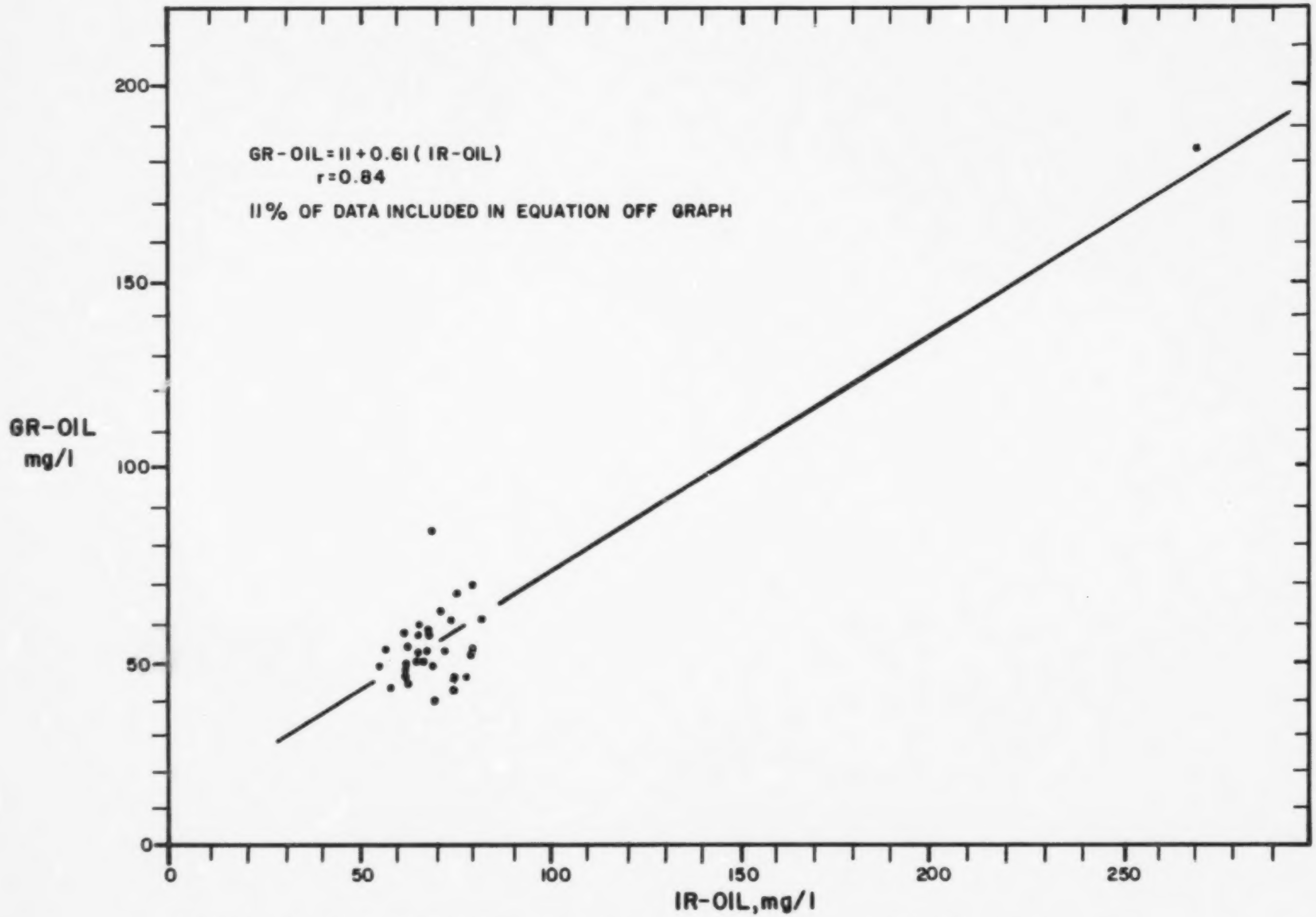


Figure 12. SP65B flotation unit effluent, infrared-gravimetric regression.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 18. SP65B FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content GR-Oil	 IR-Oil
Number of tests, (n)	38	40
Mean, ($\bar{x}$), mg/l	77	106
Minimum, mg/l	39	57
Maximum, mg/l	552	448
Standard Deviation,(s), mg/l	73	99
	Paired tests	
Number, (n)	38	
Mean of Differences, ($\bar{\Delta}$), mg/l	32	
Standard Deviation, (s_{Δ}), mg/l	56	

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 17. A summary of these test results is presented in Table 19.

On average, 62 percent of the oil in the effluent was soluble oil and 38 percent was dispersed oil.

TABLE 19. SP65B SOLUBLE OIL SUMMARY

Analysis or test	Flotation effluent Range mg/l	 Mean mg/l	Proportion of total, percent
IR-Oil	57-448	99	100
Dispersed Oil	5-331	38	38
Soluble Oil	47-117	61	62

Note: Table includes only IR-Oil tests when an IR-Oil w/Silica Gel test was run. The mean of 99 mg/l is lower than the mean of 106 mg/l for all IR-Oil tests.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 13. Extrapolating the linear regression lines to zero dispersed oil indicates a residual IR-Oil of 54 mg/l and a residual GR-Oil of 43 mg/l would still be present in the brine after all dispersed oil is removed.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

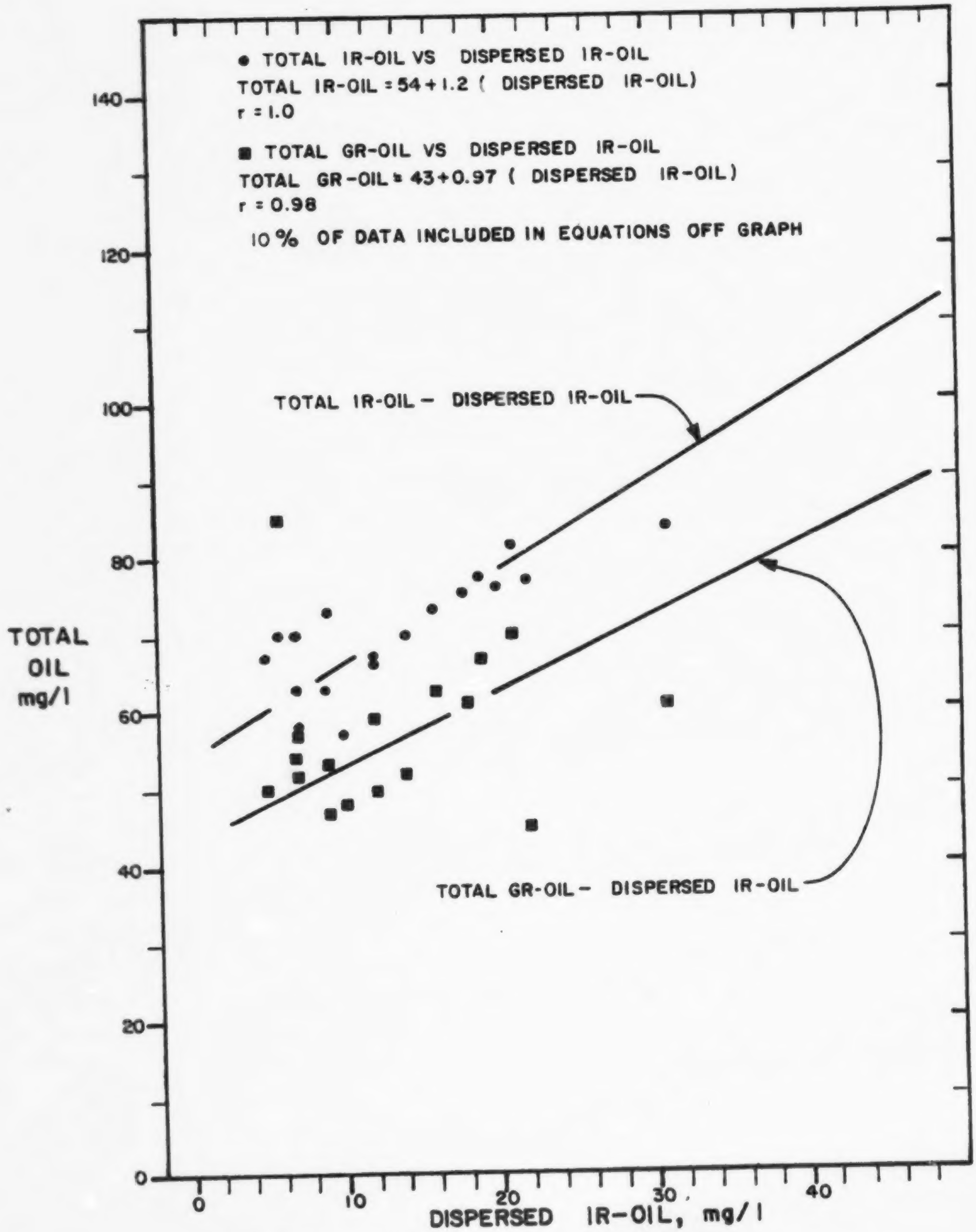


Figure 13. SP65B flotation unit effluent, total oil - dispersed oil regression.

Surface Tension

All surface tension test results are reported in Table 17. The mean surface tension of the flotation effluent is 67 dynes/cm.

Nine of the ten flotation effluent surface tension test results were in the range of 65 to 73 dynes/cm. The other result was 43 dynes/cm. The lowest value occurred on Day 1 when the chemical was not feeding and the effluent oil content was above average. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 550 - 6.9\,(\text{Surface Tension})$$
$$r = -0.96$$

The regression equation indicates a significant decrease in oil content with an increase in surface tension. The one lowest surface tension value corresponding to the highest oil content value predominated in establishing the slope of the linear regression line.

Suspended Solids

Suspended solids test data are presented in Table 20 for major sampling points.

A suspended solids summary for SP65B is presented in Table 21.

A substantial portion of the solids at all sampling points were Freon soluble. Forty-seven percent of the solids in the flotation effluent were Freon insoluble solids of which 65 percent were acid soluble.

Figure 14 presents time-indexed plots of Freon insoluble suspended solids in the flotation influent and effluent, and of flotation effluent dispersed oil. The suspended solids samples were taken at 1500 each day and the dispersed oil samples were taken at 0800 and 1300 each day.

The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when flotation influent or effluent suspended solids are higher.

Filtered Brine

The filtered brine IR-Oil content of SP65B effluent was in the range of 43 to 152 mg/l with a mean of 73 mg/l. The mean IR-Oil content of unfiltered brine on SP65B was 89 mg/l for all samples when filtered brine tests were also run.

For comparison to the effluent mean filtered brine IR-Oil of 73 mg/l, the soluble oil mean was 61 mg/l.

Flotation Unit Performance

Figure 15 is a regression plot of IR-Oil in and out of the flotation

TABLE 20. SP65B SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8--i)					Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	15	221	139	82	40	42	114	88	26	2	24	92	51	41	21	20
02	15	120	95	25	10	15	64	45	19	7	12	25	6	19	14	4
03	15	108	86	22	13	8	63	45	18	8	9	21	14	7	6	2
04	15	146	106	40	32	9	84	39	45	11	35	46	23	23	10	14
05	15	162	130	33	22	11	97	51	47	17	30	28	18	10	7	3
06	15	189	159	30	28	2	129	68	61	11	50	18	10	8	5	3
07	15	76	66	10	3	7	51	37	14	12	2	12	8	4	5	0
08	15	106	87	19	12	7	175	160	15	8	8	36	26	10	8	2
09	15	187	150	37	18	19	117	79	39	26	13	51	20	31	26	5
10	15	107	88	19	9	10	74	53	21	12	9	32	20	14	7	6
Minimum		76	66	10	3	2	51	37	14	2	2	12	6	4	5	0
Maximum		221	159	82	40	43	175	160	61	26	50	92	51	41	26	20

TABLE 21. SP65B SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 8--i	 9--i	 9--0
Total	142	97	36
Freon Soluble	111	67	20
Freon Insoluble	32	31	17
Acid Soluble	19	11	11
Fixed	13	19	6

Note: Some numbers do not check exactly because of rounding.

unit. The regression plot indicates there is a significant correlation in flotation influent and effluent oil content. The high oil content values occurring on Day 1 and Day 2 predominate in establishing the relationship. Except for those on the first two days, all other influent and effluent brine oil content values are in narrow ranges.

The flotation unit was operating at about 11 percent of design capacity. This low hydraulic loading may have been a factor in smoothing out fluctuations in effluent oil content.

Skim Tank Performance

The skim tank (gravity separator) effluent and the flotation unit influent are the same. Therefore, all data for the flotation influent (sample point 9--i) also characterize the skim tank effluent.

Skim tank in and out oil content data are presented in Table 17. The influent is highly variable. The effluent IR-Oil content mean was 170 mg/l, with a standard deviation of 147 mg/l, and a range of 91 to 692 mg/l.

The time-indexed plots in Figure 8 and Figure 9 labeled "influent" represent skim tank performance. The first four to six oil content tests are relatively high (IR-Oil 631, 692, 578, 400, 370 and 144 mg/l). As previously noted, this occurred when coagulant chemical was not added ahead of the skim tank and the influent oil content was comparatively high. The remaining test results indicate consistent performance.

For comparison to the skim tank effluent oil content, the mean oil content after sixty minutes settling under susceptibility-to-separation test conditions was 211 mg/l.

Miscellaneous Brine Tests

All other brine test results for SP65B are listed in Tables 22, 23, 24, 25, 26 and 27. The results for the following tests were in narrow ranges for

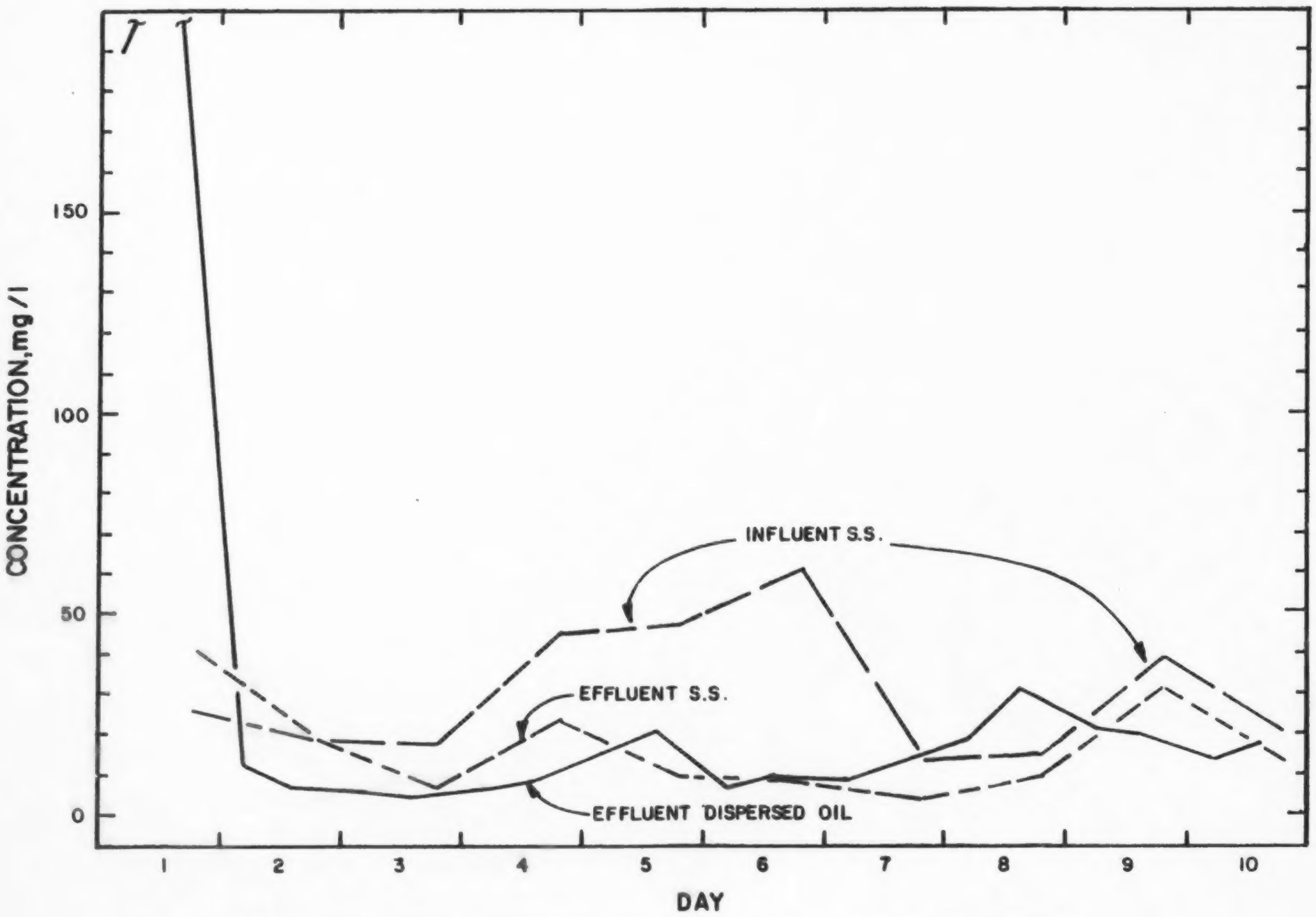


Figure 14. SP65B flotation unit Freon insoluble suspended solids.

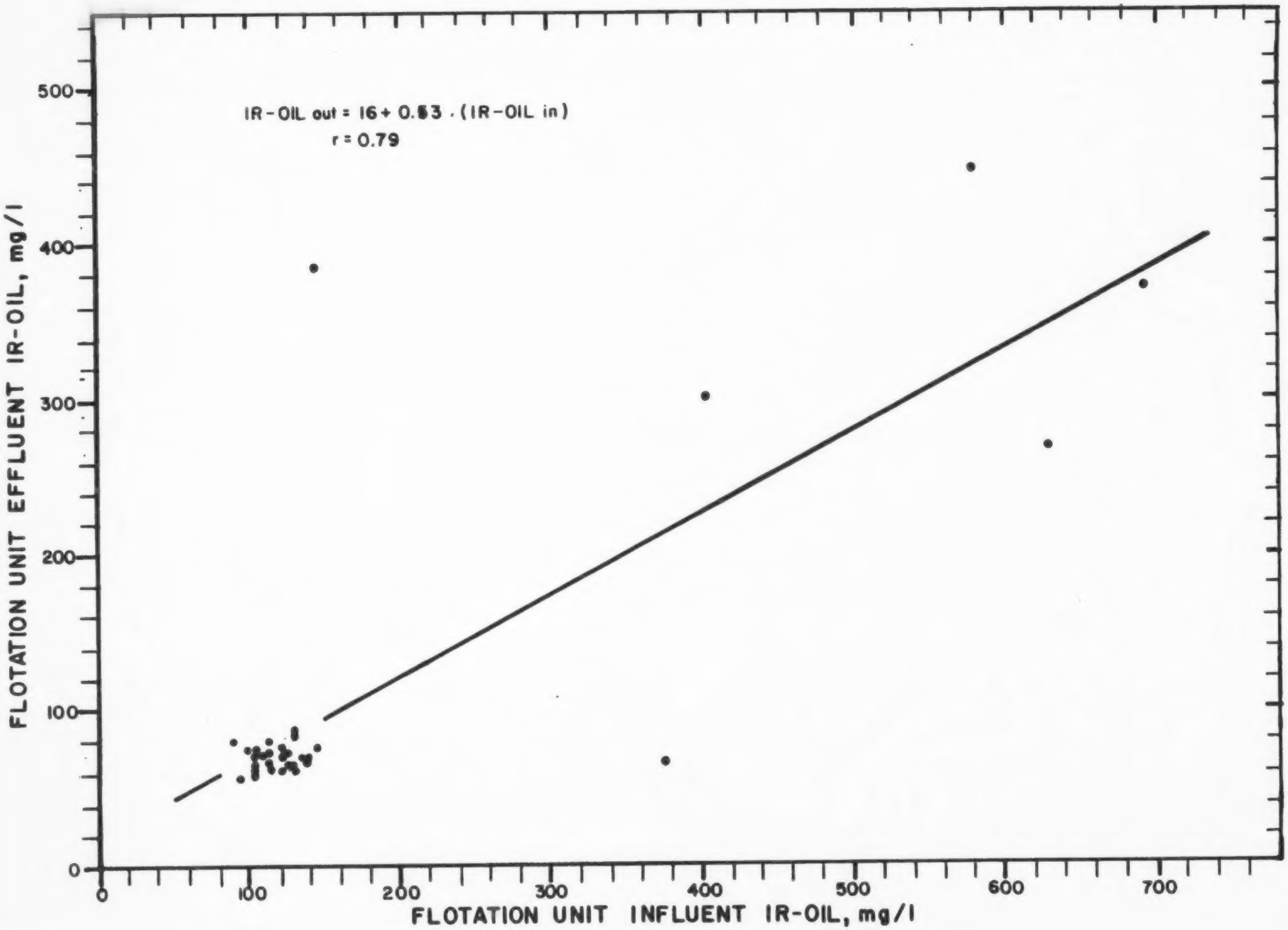


Figure 15. SP65B flotation unit in-out IR-oil regression.

TABLE 22. SP65B SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °C							pH	Specific gravity[1]
Day	Hour	13--0	14--0	5A30	6--0	8--i	9--i	9--0	9--0	9--0
01	08	-	-	-	-	-	-	35.5	-	1.082
01	10	25.5	32.7	39.0	39.1	38.1	35.4	38.0	7.0	-
02	08	-	-	-	-	-	-	37.7	-	1.086
02	10	25.5	30.8	37.7	36.5	36.0	36.5	37.8	6.8	-
03	08	-	-	-	-	-	-	37.0	-	1.085
03	10	26.5	29.5	38.5	27.5(A)	38.0	37.2	37.8	7.0	-
04	08	-	-	-	-	-	-	37.0	-	1.086
04	10	25.7	30.2	40.0	39.5	39.5	37.7	38.2	6.8	-
05	08	-	-	-	-	-	-	39.8	-	1.085
05	10	25.8	31.5	40.0	40.3	39.8	39.0	39.8	7.0	-
06	08	-	-	-	-	-	-	38.8	-	1.085
06	10	26.7	32.5	40.5	40.5	39.5	38.7	39.5	6.8	-
07	08	-	-	-	-	-	-	39.0	-	1.088
07	10	27.0	32.2	39.5	41.8	38.8	37.2	39.2	6.9	-
08	08	-	-	-	-	-	-	39.2	-	1.089
08	10	26.6	34.1	39.8	41.5	40.3	39.5	39.8	6.9	-
09	08	-	-	-	-	-	-	39.6	-	1.088
09	10	26.2	38.6	40.3	40.5	39.9	39.6	39.7	7.0	-
10	08	-	-	-	-	-	-	39.0	-	1.086
10	10	26.2	38.5	39.8	41.2	39.8	39.0	39.5	6.9	-
Mean		26.2	33.1	40.0	40.1	39.0	38.0	38.6	6.9	1.086
Minimum		25.5	29.5	37.7	36.5	36.0	35.4	35.5	6.8	1.082
Maximum		27.0	38.6	40.5	41.8	40.3	39.6	39.8	7.0	1.089

Note: Sample point identification numbers as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in the table above.
(A) Not included in statistical data. Appears inconsistent with all other measurements.

TABLE 23. SP65B LOW PRESSURE SEPARATOR EFFLUENT SUSPENDED SOLIDS

Sample time						
Day	Hour	Total	Freon soluble	Freon insoluble	Acid soluble	Fixed
08	15	88	72	16	6	10
09	15	131	94	38	20	18

TABLE 24. SP65B SULFATE REDUCING BACTERIA

Sample point	Sample No. 1	Sample No. 2
Flotation Unit - Out (9--0)	0	0
Flotation Unit - In (9--i)	0	0
FWKO - Out (5A30)	0	0
Oil Treater - Out (6--0)	0	0
Skim Pile (13--0)	0	0
Sump (14--0)	0	0

Sample Day and Hour: 04 at 13

TABLE 25. SP65B WATER CUT AT VARIOUS SAMPLE POINTS

Sample time Day	 Hour	Water cut, % Skim pile out	 Sump out
01	10	100	100
02	10	100	100
03	10	100	100
04	10	100	100
05	10	100	100
06	10	100	100
07	10	100	100
08	10	100	100
09	10	100	97
10	10	100	100
Minimum		100	97
Maximum		100	100

TABLE 26. SP65B IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	82,000
Calcium (Ca)	3,100
Magnesium (Mg)	910
Barium (Ba)	650
Chloride (Cl)	53,900
Sulfate (SO_4)	188
Alkalinity (as HCO_3)	214
Iron (Total)	4
Sulfide (as H_2S)	1.3
Total Dissolved Solids	
Summation	141,000
Gravimetric	105,000

Sample Day and Hour: 03 at 13

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 27. SP65B FWKO EFFLUENT SUSCEPTIBILITY TO SEPARATION

Sampling time	Test number 1	2	Mean
Day	4	8	-
Hour	9	9	-
Minute	30	30	-
Settling time, minutes	**IR-Oil, mg/l**		
0-1 (1)	409	313	361
5	331	291	311
15	331	270	300
30	270	209	240
60	231	191	211
120	144	113	128

(1) The actual settling time is the time required to handle the separatory funnel after filling and to draw a sample, and is estimated at not more than one minute.

all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content on SP65B. These parameters will be discussed with respect to variations between platforms in Section 17.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on SP65B. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil test results are listed in Tables 28 and 29. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one or two and are of primary significance for comparisons between platforms. Two equilibration tests were run.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE 28. SP65B CRUDE OIL MISCELLANEOUS TESTS[1]

Sample time Day	Hour	Temperature °C	Specific gravity[2]	Surface tension[2] dynes/cm
01	08	32.7	0.869	30
02	08	36.5	0.866	30
03	08	32.0	0.866	30
04	08	34.2	0.866	30
05	08	32.0	0.860	30
06	08	39.0	0.864	31
07	08	39.5	0.863	31
08	08	38.2	0.863	30
09	08	38.8	8.865	30
10	08	36.7	0.865	28
Mean		36.0	0.865	30
Minimum		32.0	0.860	28
Maximum		39.5	0.869	31

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
03	10	9.51	8.24

	Equilibration at 82°C Brine TDS = 100,000 mg/l	
	Test No. 1	Test No. 2
Oil/Water Ratio	4/1	4/1
IR-Oil, mg/l	50	56

---

(1) Samples taken from LACT unit.
(2) Reported for approximately the temperature in table.

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 29. SP65B CRUDE OIL BOILING RANGE DISTRIBUTION

	Run No. 1	Run No. 2	Mean
Initial Boiling Point, °C	150	150	150
Final Boiling Point, °C	480	480	480
Boiling range, °C	Percent recovered		
Below - 200	46.3	51.9	49.1
200 - 250	10.9	9.9	10.4
250 - 300	14.6	14.6	14.6
300 - 350	16.1	12.9	14.5
350 - 400	5.2	4.8	5.0
400 - 450	5.7	5.0	5.4
450 - 500	1.1	0.5	0.8
500 - 550	0.2	0.3	0.2
Total	100.1	99.9	100.0

Sample Day and Hour: 03 at 10

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

SECTION 7

PLATFORM WD45C

GENERAL

A complete ten-day test program was conducted on Platform WD45C from June 25 to July 4, 1979. Tests were added to the program plan in the field because additional wells, one low-pressure separator, and one gun barrel were put in service after the plan was developed.

Company personnel provided the facilities, accommodations, and operational information needed for a successful survey. A Company staff engineer assisted with the program for the first nine days.

One complete production shutdown occurred, but it was so brief that it did not affect the survey.

FACILITIES AND OPERATIONS

Production From Wells

A total of 29 wells were in production for at least one day during the survey period. Several of the wells did not produce continuously.

All production flowed or was gas lifted to three low-pressure gas/liquid separators. The average daily production calculated from well test data was 388 m^3/d (2,440 bpd) of oil, 684 m^3/d (4,305 bpd) of water, and 69,560 std m^3/d (2,458 Mcfd) of gas. The combined water cut was 64 percent.

The measured oil production for the ten-day period averaged 370 m^3/d (2,330 bpd) or 4.5 percent less than the calculated production.

Eight percent of the oil and 1.7 percent of the water were gas lifted.

Production Process System

The flow of oil and water through the system is shown in Figure 16. Design and operating data on major vessels are presented in Table 30. All wells flowed to one of three low-pressure two-phase separators in parallel. The liquids then flowed to two gun barrels also in parallel. Oil recovered from each gun barrel went to storage. A combined water stream from the two gun barrels flowed to the flotation unit for treatment.

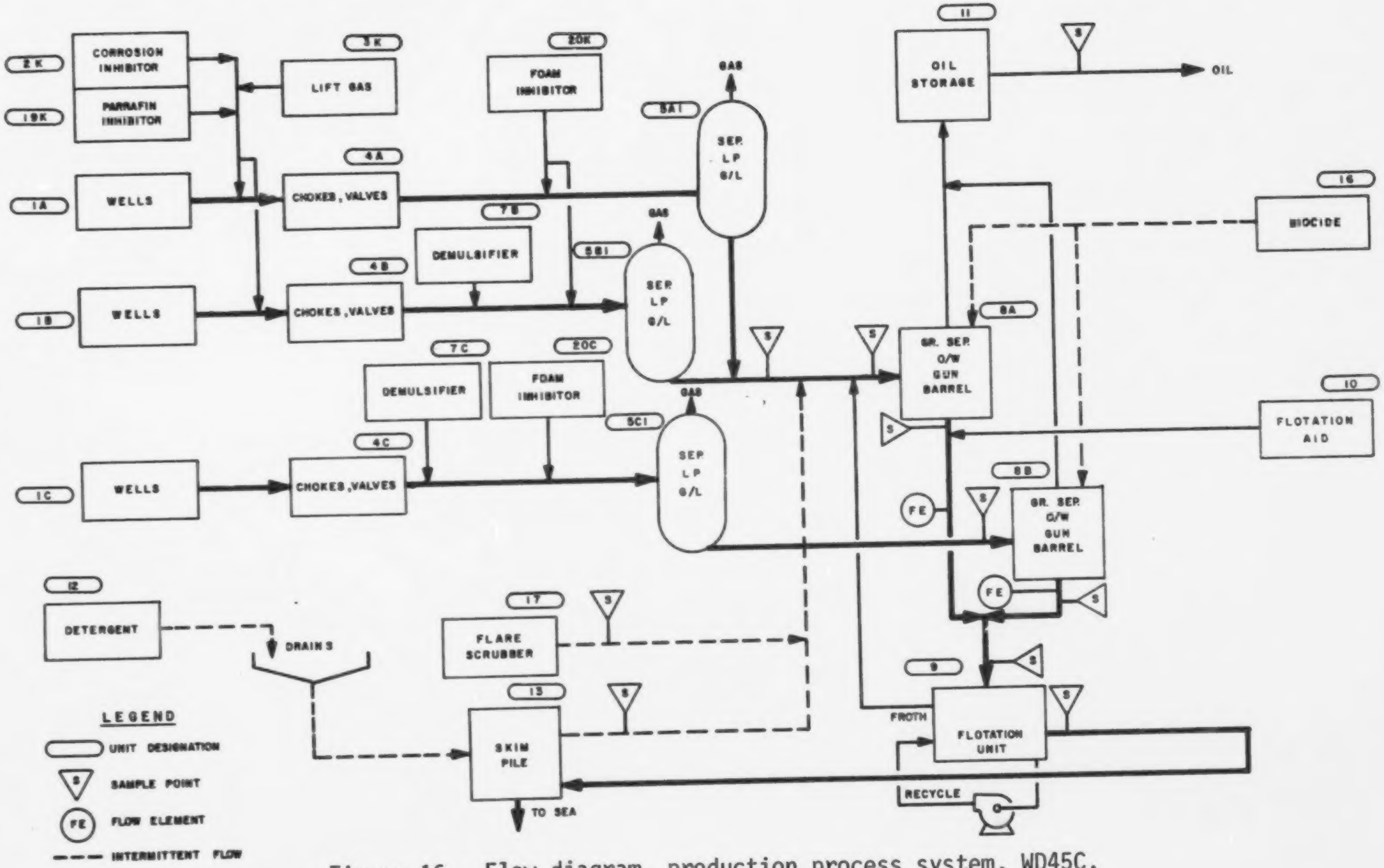

2K
CORROSION INHIBITOR
19K
PARRAFIN INHIBITOR
3K
LIFT GAS
20K
FOAM INHIBITOR
GAS
5A1
SEP. LP G/L
11
OIL STORAGE
S
OIL
1A
WELLS
4A
CHOKES, VALVES
16
BIOCIDE
7B
DEMULSIFIER
5B1
GAS
SEP. LP G/L
1B
WELLS
4B
CHOKES, VALVES
S
S
8A
GR. SEP. O/W GUN BARREL
7C
DEMULSIFIER
20C
FOAM INHIBITOR
GAS
5C1
SEP. LP G/L
10
FLOTATION AID
S
1C
WELLS
4C
CHOKES, VALVES
8B
FE
S
GR. SEP. O/W GUN BARREL
FE
S
12
DETERGENT
DRAINS
17
FLARE SCRUBBER
S
S
9
13
S
SKIM PILE
TO SEA
FROTH
FLOTATION UNIT
S
RECYCLE
LEGEND
UNIT DESIGNATION
S SAMPLE POINT
FE FLOW ELEMENT
INTERMITTENT FLOW

Figure 16. Flow diagram, production process system, WD45C.

TABLE 30. WD45C VESSEL DATA SHEET

Vessel description	5A1 Low pressure gas/liquid separator	5B1 Low pressure gas/liquid separator	5C1 Low pressure gas/liquid separator	8A Gravity separator, gun barrel	8B Gravity separator, gun barrel	9 Flotation unit, hydraulic, dispersed gas
	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 7-1					
Trade Name or Vessel Type	Vertical Cylinder	Sphere	Vertical Cylinder	Vertical Cylinder	Vertical Cylinder	Monosep Model AG6000
Design Parameters						
Dimensions, m, (ft) (1)						
Diameter, O.D.	-	-	-	3.66(12)	3.66(12)	-
Length, S.S.	-	-	-	-	-	-
Length	-	-	-	-	-	3.05(10)
Width	-	-	-	-	-	2.29(7.5)
Height	-	-	-	6.1(20)	6.1(20)	1.83(6)
Surface Area, m^2, (ft^2)						
Separation Total	-	-	-	10.5(113)	10.5(113)	5.1(55)
Per Cell	-	-	-	-	-	-
Separation Volume, m^3, (bbl)						
Total	-	-	-	57(360)	64(400)	9.2(58)
Oil Phase	-	-	-	13(80)	16(100)	-
Water Phase	-	-	-	44(280)	48(300)	-
Number of Cells						1
Flow Rate, m^3/day, (bpd)	-	-	-	-	-	981(6170)
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2) (4)	-	-	-	-	-	192(112)
Recycle Rate, Percent of Flow	-	-	-	-	-	400
Retention Time, min.	-	-	-	-	-	14
Average Operating Parameters						
Temperature, $^oC(^oF)$	-	-	-	40.4(105)	40.0(104)	40.0(104)
Pressure, kPag, (psig)	360(52)	410(59)	310(45)	-	-	-
Flow Rate, m^3/d (bpd)(2)	-	-	-	398(2501)	363(2286)	691(4347)(3)
Flow Rate, Percent of Design	-	-	-	-	-	70
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)	-	-	-	38(22)	35(20)	135(79)
Recycle Rate, Percent of Flow	-	-	-	-	-	570
Froth Flow, Percent of Flow	-	-	-	-	-	10

(1) Tank dimension.
(2) Water flow only.
(3) Effluent flow.
(4) Overflow rate is surface area divided by flow rate.

As shown in the flow diagram, one gun barrel receives only produced fluids. The other gun barrel receives produced fluids, fluids from the skim pile, the flare scrubber, and froth recycle from the flotation unit.

Figure 17 is a flow schematic for the water handling portion of the system. A nominal average water flow balance is presented in the figure. The produced water flowed continuously to and from the gun barrels at approximately the average daily rate shown.

Froth was returned to the "A" gun barrel from the froth chamber of the flotation unit on level control. The pumping rate was 327 m^3/d as required.

Fluids were returned to the "A" gun barrel from the skim pile, at a rate of 327 m^3/d. The pump was controlled by a timer which actuated the pump every two hours and ten minutes. Pumping duration was just over 2.5 minutes each time.

Several cubic decimeters of fluid were drained from the flare scrubber once a week.

A flotation aid, Nalco 3349, was added to the "A" gun barrel effluent at the rate of 4.5 dm^3/d.

The gun barrels are dual-purpose units. They provide gravity separation of water from oil to prepare the oil for sale. They also provide primary separation of oil from the water to prepare the water for treatment by flotation.

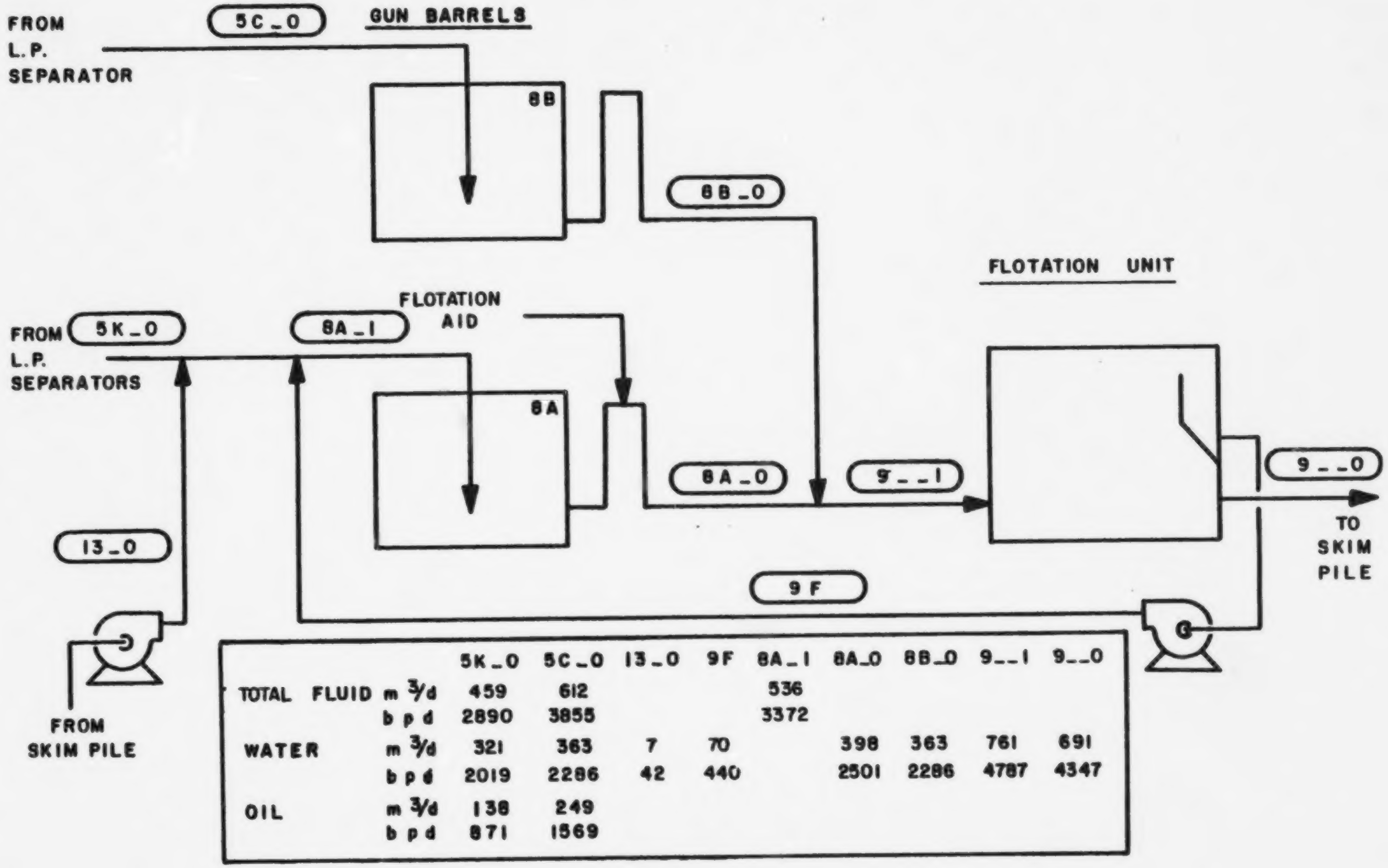
The gun barrels are vertical cylindrical tanks. Figure 18 is a dimensional sketch which also shows probable flow patterns. The water and oil enter through a centrally located inlet pipe which discharges near the bottom. The water outlet is near the bottom of the tank wall. Level control is by a water leg.

The volume below the inlet distributor of each gun barrel is 12.7 m^3(80 bbl). At the average water flow rate for the "A" gun barrel of 398 m^3/d (2,501 bpd), the calculated average residence time would be 46 minutes. The effective residence time would be less because of short-circuiting between the inlet and outlet. Short term flow rates would be much higher than the average rate when water is being returned from the flotation unit or skim pile.

Physically, the "B" gun barrel is identical to the "A" gun barrel. The average flow rate to the "B" gun barrel was lower. It receives continuous flow of produced water and none of the intermittent flows.

There is not a standard procedure for calculating the theoretical oil/water separation capability for units of the configuration of these gun barrels. The jet-like inflow and potential for short circuiting limit the effectiveness of the gun barrels as water treating gravity separators.

The polishing unit is a proprietary one-cell dispersed gas flotation unit (Monosep AG-6000). Figure 19 is a sketch of the unit. The unit


FROM
L.P.
SEPARATOR
5C_0
GUN BARRELS
8B
8B_0
FLOTATION UNIT
FLOTATION
AID
FROM
L.P.
SEPARATORS
5K_0
8A_I
8A
8A_0
9__I
9__0
TO
SKIM
PILE
13_0
9F
FROM
SKIM PILE

		5K_0	5C_0	13_0	9F	8A_I	8A_0	8B_0	9__I	9__0
TOTAL FLUID	m ³/d	459	612			536				
	b p d	2890	3855			3372				
WATER	m ³/d	321	363	7	70		398	363	761	691
	b p d	2019	2286	42	440		2501	2286	4787	4347
OIL	m ³/d	138	249							
	b p d	871	1569							

Figure 17. WD45C water handling system flow schematic.

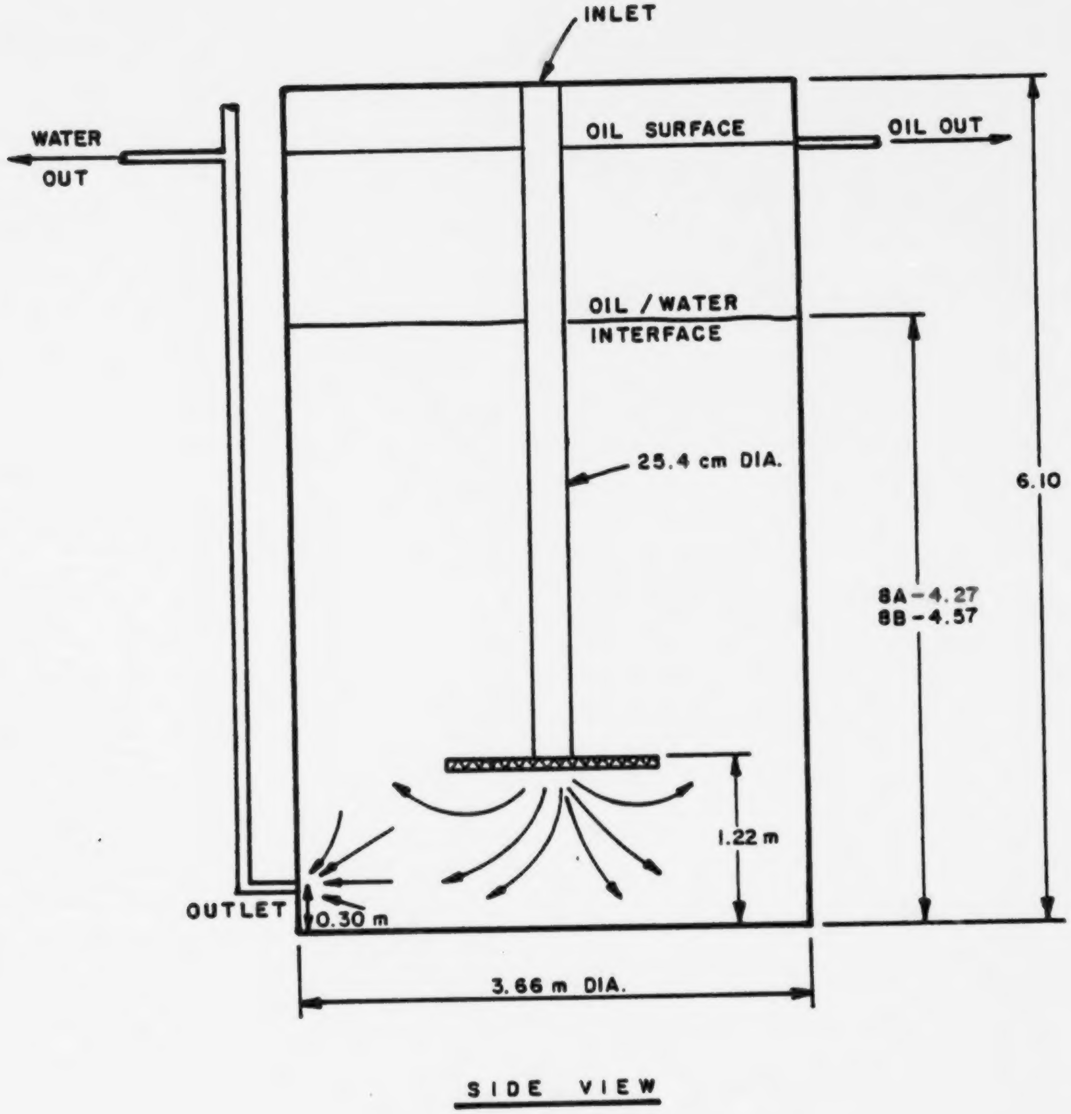
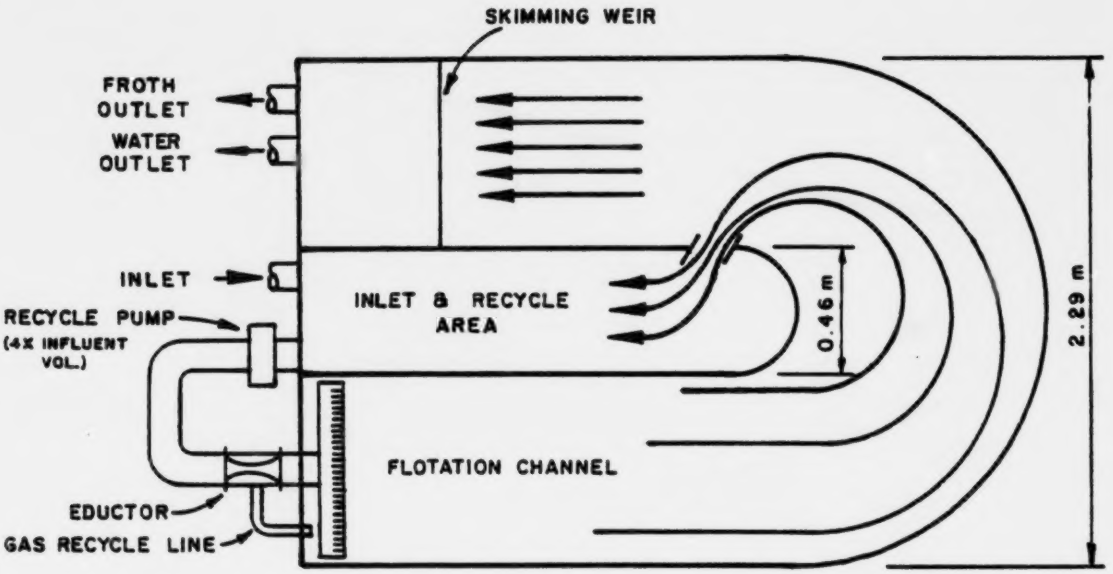
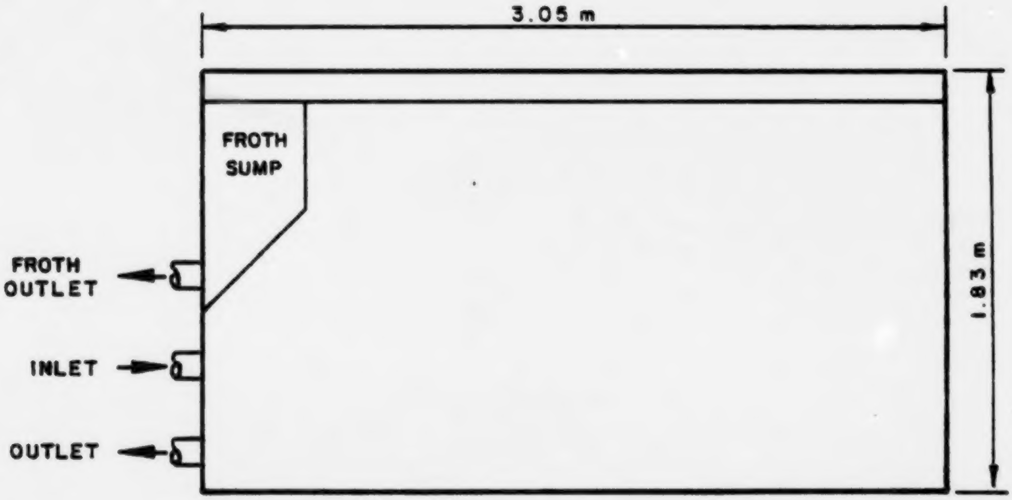

INLET
WATER
OUT
OIL SURFACE
OIL OUT
OIL / WATER
INTERFACE
25.4 cm DIA.
6.10
8A - 4.27
8B - 4.57
1.22 m
OUTLET
0.30 m
3.66 m DIA.
SIDE VIEW

Figure 18. WD45C gun barrel 8A & 8B


SKIMMING WEIR
FROTH OUTLET
WATER OUTLET
INLET
RECYCLE PUMP
(4X INFLUENT VOL.)
INLET & RECYCLE AREA
0.46 m
2.29 m
FLOTATION CHANNEL
EDUCTOR
GAS RECYCLE LINE

TOP VIEW


3.05 m
FROTH SUMP
FROTH OUTLET
INLET
OUTLET
1.83 m

SIDE VIEW

Figure 19. WD45C flotation unit sketch.

TYPING GUIDE SHEET

operates gas blanketed. Gas for flotation is educted hydraulically. Froth is removed over a single weir at the outlet end. The recycle water flow for gas dispersion is 400 percent of the design forward flow.

The design flow for the unit was 981 m^3/d (6,170 bpd). The average operating flow rate was 691 m^3/d (4,347 bpd), based on effluent flow or 70 percent of design flow. The average froth flow was 70 m^3/d (440 bpd) or 10 percent of the forward flow.

SITE SPECIFIC TEST PROGRAM

The approved program plan could not be followed because at the time of the survey more equipment was in operation than at the time the plan was developed. It was necessary to add sample points and additional tests.

The revised flow diagram was presented in Figure 16. The revised schedule for major brine tests is presented in Table 31. As for all platforms, samples were taken at nominal sampling times of 0800, 1000, 1300, and 1500 hours on each of the ten days.

Particle size distribution data were obtained on WD45C and are discussed separately in Section 16.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operating conditions are reported in this subsection.

Flow Monitoring

The clamp-on flow monitor was applied alternately to each of the gun barrel effluent lines. The monitor could not be zeroed in the recommended manner, and the measured flow rates did not match estimates from well test data. After the fifth day, the flow measurements were erratic and not in a believable range.

During the first four days the monitor appeared to provide reasonable flow variability measurements. An eight hour continuous flow record for each gun barrel is presented in Figure 20.

The flow from the "A" gun barrel cycled up and down, mostly in the range from 220 to 380 m^3/d. The average measured flow for the period covered was about 300 m^3/d, compared to 380 m^3/d as estimated from well test data. Water flow to the "A" gun barrel could be substantially over 550 m^3/d when the froth pump and skim pile pump were operating. However, either the flow variation was damped by the gun barrel or the monitor was not detecting the maximum flows.

The flow pattern for the "B" gun barrel also followed a cyclic pattern. The average measured flow was about 330 m^3/d, in the range from 245 to 410 m^3/d. The flow estimated from well test data for the same period was 380 m^3/d.

EPA-287 (Cin.)
(4-76)

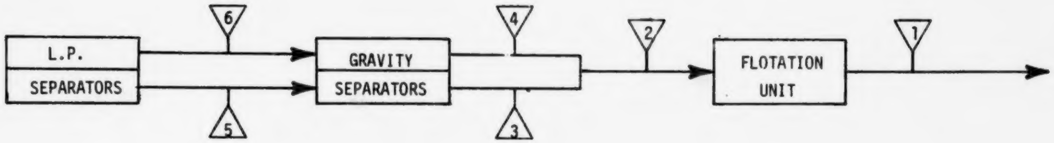


TABLE 31. WD45C TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS											
	1 9--0		2 9--i		3 8A-0		4 8B-0		5 8A-i		6 8B-i	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests												
Infrared Oil	40	8,10,13,15	40	8,10,13,15	20	10,15	20	10,15	-	-	-	-
Temperature	20	8,10	10	10	10	10	10	10	10	8	-	-
pH	10	10	-	-	-	-	-	-	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-	-	-	-	-	-	-
Water Surface Tension	10	8	-	-	-	-	-	-	-	-	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	-	-	-	-	-	-	-	-
IR-Oil Filtered Brine	10	8	-	-	-	-	-	-	-	-	-	-
Susceptibility to Separation	-	-	3	(1)	-	-	-	-	-	-	-	-
Laboratory Tests												
Gravimetric Oil	40	8,10,13,15	20	8,13	-	-	-	-	-	-	-	-
Suspended Solids	10	15	10	15	-	-	-	-	-	-	-	-
Ionic Analysis	1	(1)	-	-	-	-	-	-	-	-	-	-
Bacterial Culture	1	(1)	1	(1)	-	-	-	-	-	-	-	-
Particle Size Distribution	3	(1)	-	-	3	(1)	3	(1)	3	(1)	-	-

(1) Sampling times not shown will be field scheduled.

NOTE: Time of tests listed is by military hour. Some of the one-a-day samples were not scheduled for a certain hour and are listed at the time actually run.

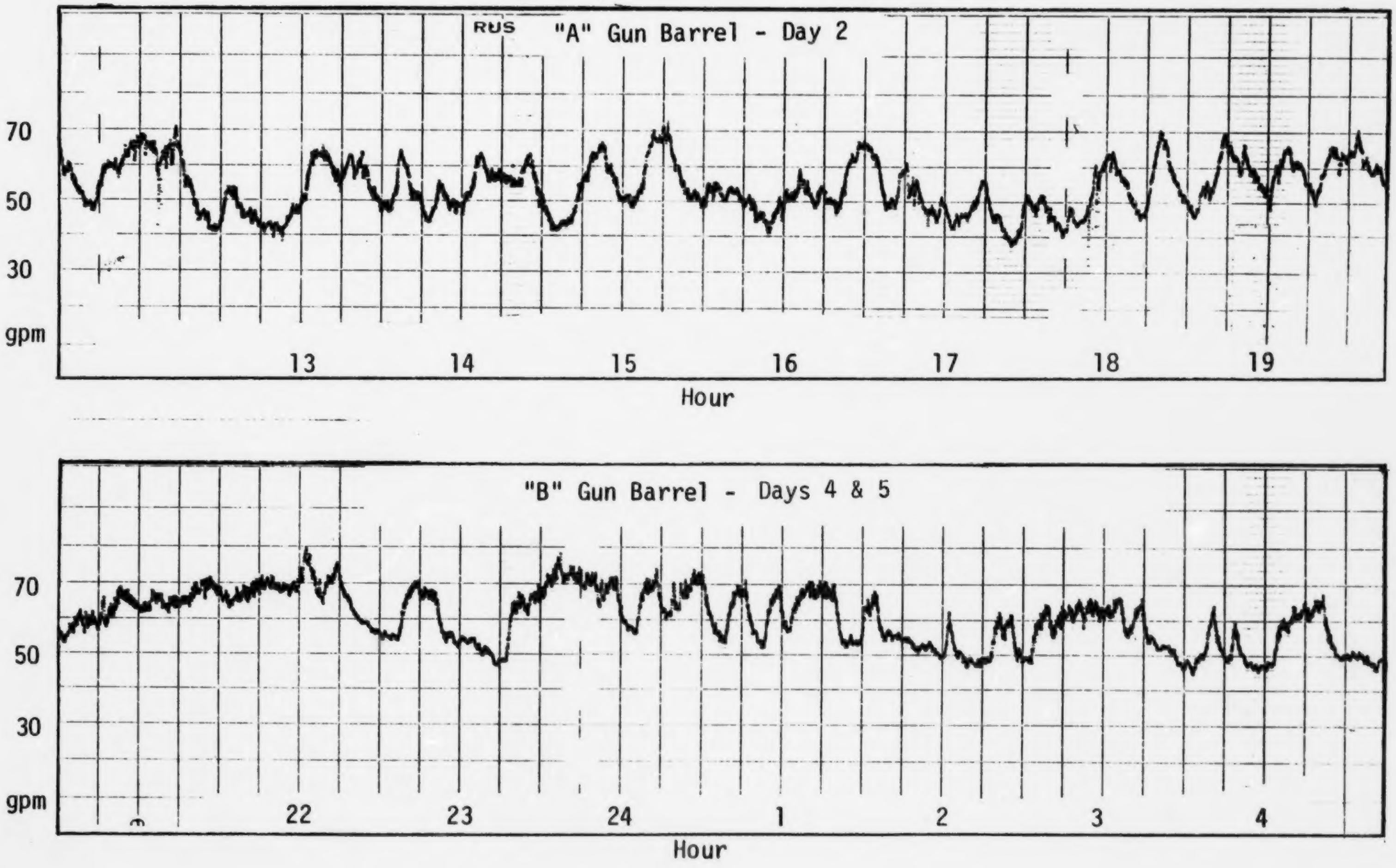


Figure 20. Flow chart WD45C gun barrel effluents.

TYPING GUIDE SHEET

Well test data are considered more accurate than the flow monitor data for estimating average hydraulic loading of the gun barrels and flotation unit.

Well Test Data

Well test data provided by the operator are presented in Table 32. The well data are separated in groups according to which gun barrell ultimately received the flow. Data for gas-lift wells are also grouped separately. All wells flow first to a low-pressure two-phase separator. The table also shows whether a well produced all the time or for only part of the survey period.

The water balance flow rates previously presented in Figure 17 were calculated from the well test data.

As reported earlier, measured oil production and production calculated from well test data were within 4.5 percent of each other. This lends confidence to the water balance estimates.

Vessel Temperature and Pressures

The pressure of each of the three low-pressure separators was recorded twice per day. All other vessels were at atmospheric pressure. The temperature of the effluent from each vessel was measured once per day.

Temperature and pressure ranges for the ten-day period are presented in Table 33.

The table indicates significant temperature and pressure variations during the test period.

Pressure Drops Through System

Table 34 presents pressure drops from the producing formations through the system.

The table includes only the wells producing water. For comparison, the table shows that the greatest pressure drops occur from the formation to the chokes, substantial drops occur at the chokes, and more minor drops from the chokes on.

The pressure drop data are recorded to permit examining the theory that pressure drops and turbulences may result in small-drop dispersions that are difficult to remove in separation equipment.

Chemical Addition

Five chemicals were added by metering pumps as listed in Table 35.

The foam inhibitor was diluted with diesel and fed at concentrations of 1-3 percent. The other chemicals listed in Table 35 were fed neat.

EPA-287 (Cin.)
(4-76)

TABLE 32. WD45C WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig		Choke size 1/64 in.	API gravity	Days of production
							SIBHP	FTP			
Gun Barrel 8A Wells Flowing to Low Pressure Separator											
B-4-	JCAB4	7,862	66	18	0	0	3,793	350	6.0	27.4	All
B-9D	GG-B5	6,068	62	316	5	0	2,550	300	14.5	28.6	All
B10-	JCNC4	7,416	85	39	351	0	3,800	600	11.0	24.4	All
B10D	IM---	7,271	65	0	285	0	4,350	750	10.0	-	1,4,5(AM)6,7,8,9,10
B11-	JACB11	8,896	172	98	183	0	4,105	725	11.0	26.1	All
B11D	IMB11	8,511	84	50	22	0	4,095	180	14.0	29.2	1,2,3,4,5(AM)6,7(AM)
C-4D	FQ-C4	5,505	42	31	46	0	2,415	225	10.0	21.9	All
C-6D	JCJC4	7,416	17	38	0	0	2,987	325	6.0	29.5	All
C-8T	IM-C8	8,734	44	3	124	0	4,860	1,150	6.0	29.2	1,2,3
C10D	IMC10	8,743	28	9	866	0	4,912	850	13.0	30.6	All
C11D	HKC11	7,219	32	58	232	0	3,449	420	12.0	26.8	All
Total (Average)		(7,604)	697	660	2,114	-	(3,756)	(534)	(10.3)	(27.4)	
Gas Lift to Low Pressure Separator											
B-9-	JAAB9	7,634	458	192	29	400	2,390	350	23.0	28.6	All
C-7T	FSUC1	5,619	149	8	45	-	2,454	280	17.0	25.2	All
Total (Average)		(6,626)	607	200	74	1169	(2,422)	(315)	(20.0)	(26.9)	
8A Total (Avg)		(7,453)	1,304	860	2,188	1169	(3,551)	(500)	(11.8)	(27.3)	
Gun Barrel 8B Wells Flowing to Low Pressure Separator											
H-1-	FSLC7	5,603	64	253	170	0	2,413	300	17.0	24.2	All
H-1D	FQ-C1	5,469	54	205	138	0	2,378	325	14.5	20.2	All
H-2-	JABC5	8,836	17	53	99	0	3,223	300	10.0	18.8	All
H-2D	GG-C1	6,297	11	51	152	0	2,915	160	15.0	18.8	All
H-3-	IF-C2	7,329	32	160	149	0	3,219	160	17.0	24.6	All
H-3D	GG-E1	6,206	211	68	274	0	2,840	400	17.0	20.6	All
H-4D	JABC4	7,269	125	302	164	0	2,725	260	22.0	27.5	All
H-5D	GG-C1	6,229	18	110	9	0	3,420	515	7.0	28.9	4(PM)5,6,7,8
H-6-	JAAC5	8,151	169	68	160	0	3,924	830	7.0	29.6	All
H-6D	GG-B5	6,236	156	71	214	0	2,834	225	18.0	20.5	All
H-7D	JAAC8	8,875	40	50	282	0	3,978	700	10.0	26.8	1,2,3,4,5
H-9-	JABC5	8,408	108	52	157	0	3,242	250	14.0	29.9	All
H-9D	IMC10	8,100	28	46	86	0	2,953	280	11.0	29.9	All
H12D	FSLC7	5,608	157	79	320	0	2,465	225	24.0	24.1	All
H14D	FSUC1	5,547	32	78	42	0	2,470	360	9.0	25.1	All
8B Total (Average)		(6,944)	1,222	1,646	2,416		(3,000)	(353)	(13.3)	(24.6)	
8A & 8B Total (Avg)		(7,180)	2,526	2,506	4,604	1169	(3,256)	(421)	(11.3)	(25.8)	
Temporary											
C-6-	JCNC4	7,492	306	269	0	0	2,767	675	14.0	21.2	4

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTION HERE

TABLE 33. WD45C VESSEL TEMPERATURES AND PRESSURES

Vessel	Pressure, kPag (psig)	Temperature, °C
Low Pressure Separator 5A1	276-552 (40-80)	-
Low Pressure Separator 5A2	386-600 (56-87)	-
Low Pressure Separator 5A3	262-490 (38-71)	-
Gun Barrel 8A	0 (0)	38.0-41.8
Gun Barrel 8B	0 (0)	39.0-40.6
Flotation Unit 9	0 (0)	36.8-46.0

TABLE 34. WD45C PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Formation (SIBHP)	16,400-33,870 (2,378-4,912)	perforations, static head, pipes	14,065-28,010 (2,040-4,062)
Flowing Tubing Pressure	1,105-7,930 (160-1,150)	chokes, valves, pipes	795-7,520 (115,-1,091)
Low Pressure Separators	260-600 (38-87)	control valve, pipes	260-600 (38-87)
Skim Tank	0		

BEGIN LAST LINE OF TEXT
3/8"
OTTOM OF IAGE AREA, UTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 35. WD45C CHEMICAL ADDITION

Chemical	Flow diagram identifier	Addition point	Gun barrel	Addition rate		Operation
				dm^3/d	ppmv	
Nalco 970, "Gas-Cor" (Gas system corrosion inhibitor)	2K	Lift gas line to all gas lift wells	-	1.9	-	Continuous after Day 1 at 1330
Nalco 914, "Visco" (Paraffin control)	19K	Lift gas line to all gas lift wells	-	3.4	-	Malfunctions on Day 1 until 1330, evening Day 3 until Day 5 at 1430 and morning Day 6 until afternoon Day 7
Tretolite RP 79 (Demulsifier)	7B	Well manifold ahead of 5B1	8A	8.3	16(1)	Continuous
	7C	Well manifold ahead of 5C1	8B	6.4	10(1)	Continuous
Dow 200 (Foam inhibitor)	20K	Between wells and 5A1 and 5B1	8A	0.8	1.4(1)	Continuous
	20C	Well manifold ahead of 5C1	8B	1.1	1.9(1)	Continuous
Nalco 3349, "Koagulant" (Water treatment)	10	Effluent from 8A gun barrel	-	4.5	7(2)	Malfunction on part of Day 4 and 5

(1) Based on average fluid flow into the gun barrel.
(2) Based on average flow of water discharged from the flotation unit.

Chemical usage was monitored by measuring the chemical level in the feed pump reservoirs twice a day. Interruptions in feed pump operation are shown in Table 35. The pump for water treatment chemical, Nalco 3349, stopped pumping liquid some time during Day 4 and was not repaired until about 1330 on Day 5. On Day 4, from 0630 to 1815, the pump added chemical at a rate of 1.5 dm^3/d (0.4 gpd). This is less than half the average operating rate of 4.5 dm^3/d (1.2 gpd) shown in Table 35.

The gun barrels are treated with biocide once per month. The gun barrels were treated on June 22, 1979, three days before the Program started. Thirty sticks of Tretolite Fludex, WF 75S, were added to each gun barrel. Fludex is a multi-purpose water-treatment additive. The treatment alternates monthly from Fludex one month to Tretolite X-CIDE 370 the next month.

About one cubic meter of packing fluid from well B11D flowed to the 8A gun barrel on Day 8. This incident is discussed in the following subsection. During this incident, additional chemicals were added to moderate the adverse effect of this packing fluid on the pipeline oil BS&W content and the flotation unit effluent oil content. The chemicals were added both continuously and on a batch basis. Tretolite F17 was added continuously at two places between the well and low-pressure separator 5A1. One pump added 1.1 dm^3 between 1200 and 1645. The other pump added 1.5 dm^3 from 1230 to 1530. The batch treatment was accomplished by dumping the chemical in the flotation unit froth sump which then pumped it to the 8A gun barrel. The batch treatments are listed in Table 36.

TABLE 36. WD45C CHEMICAL BATCH TREATMENTS

Chemical	Time	Quantity, dm^3 (gal)
Tretolite F17	1250	11.4 (3)
Nalco 3349	1335	3.8 (1)
Tretolite F17	1330-1400	11.4 (3)

Observations and Operator Reports

An effort was made to record any event that could affect effluent water oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures, and the survey team made their own observations. Well production interruptions longer than half a day are shown in Table 32, Well Test Data. The interruptions and changes that could have an effect on the treating system are discussed in the following sentences.

Several well changes could have had an effect on the treating system on Day 4. Well B10D which flows to low-pressure separator 5A1 began producing at 1630 on Day 3. This well produces 45 m^3/d (285 bpd) of fluid according to well test data. Well C6 "loaded up" and "died" the night of Day 3. In order to "unload" the well, it was changed from the high-pressure system to low-pressure separator 5B1. This well produced 43 m^3/d (269 bpd) of fluid according to well test data. These two wells added 88 m^3/d (554 bpd) of flow to gun barrel 8A. This is a 16 percent increase in flow over the average 536 m^3/d (3,372 bpd). Well C6 returned to the high-pressure system at 0800 on Day 5.

The morning of Day 4 at 0730 the flotation unit influent was unusually high in oil content. Table 37 lists the visual observations that followed.

TABLE 37. WD45C DAY 4 8A GUN BARREL OBSERVATIONS

Time	8A gun barrel	
	Influent	Effluent
0730	-	Lots of sand.
1030	No sand.	Sand and fluctuating quality.
1100	-	2% oil and 1% solids.
1200	-	Much cleaner.
1600	-	No free oil or solids.

All wells were shut in part of the afternoon of Day 4. Table 38 lists the times for this shut in.

TABLE 38. WD45C DAY 4 PLATFORM SHUT IN

Platform	Shut in	Open
B	1200	1445
C	1330	1430
H	1330	1500

The low-pressure separator maximum pressures occurred at 1600 on Day 4. Well B11D was shut in at 1200 on Day 7. The purpose of the shut in was to change the well from a flowing well to a gas lift well. To accomplish this change, the calcium bromide packing fluid had to be displaced. The oily packing fluid was processed through the treatment system. The discharge of packing fluid from the well began about 1130 on Day 8 and was completed about 1600.

Three deck washings were performed to clean up spilled oil. The soap was DW-9 Rig Wash from M-Chem. Table 39 lists the incidents and times.

TABLE 39. WD45C DECK WASHING

Day	Washdown period	Subsequent skim pile pumping
05	0730-0900	1100
06	1500	1500
07	0630-1000	1000

It rained on Day 6 from 1500 to 1600. The flow was to the skim pile, and the flow through the treating system was not increased.

The flotation unit froth flow was calculated twice per day from the froth sump fill time. The flow averaged 70 m^3/d (440 bpd). The minimum flow was 5 m^3/d (31 bpd) which occurred on the afternoon on Day 5, both times on Day 6, and in the morning on Day 9. The maximum flow rate was 177 m^3/d (1,110 bpd) at 1200 on Day 7.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables, summary tables, and graphs are interspersed in the text.

Effluent Oil Content

Table 40 presents a listing of all oil content tests. The ranges of test results are as follows:

Flotation Effluent GR-Oil - 17 to 465 mg/l,
Flotation Effluent IR-Oil - 31 to 516 mg/l,
Flotation Influent GR-Oil - 76 to 12,512 mg/l,
Flotation Influent IR-Oil - 98 to 15,577 mg/l.

Figure 21 is a plot of GR-Oil content in and out of the flotation unit versus time. Figure 22 is a similar plot for IR-Oil content. The graphs exhibit three effluent oil content peaks that are substantially above the typical range during the ten-day test period. The effluent peaks correspond with influent peaks.

The oil content peak on Day 4 corresponded with an above average flow to the "A" gun barrel as described in the subsection on field observations.

The feed pump for the water treating chemical was off from the middle of Day 4 to about 1330 hours on Day 5. Any effect on effluent oil content should have been apparent on the first two samples on Day 5. There was no apparent effect since the tests on both samples were in the typical range.

The cause of the oil content peak on Day 5 was not determined. As discussed earlier, some washdown water containing detergent could have been

TABLE 40. WD45C MAJOR BRINE TESTS

		Gun barrel effluents		Flotation unit influent (9--i)		Flotation unit effluent (9--0)							
		(8A-0)	(8B-0)					IR-Oil w/silica gel		Filtered brine	Surface tension	Flow rate	
Sample time		IR-Oil	IR-Oil	GR-Oil	IR-Oil	GR-Oil	IR-Oil	Dispersed	Soluble	IR-Oil		Out(2)	Skimmings
Day	Hour	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	-	-	467	445	27	43	27	16	28	60	737	28
01	10	187	66	-	498	17	31	-	-	-	-	737	28
01	13	-	-	99	125	22	36	20	16	-	-	737	28
01	15	543	78	-	151	35	45	-	-	-	-	737	28
02	08	-	-	328	392	22	35	20	15	28	59	692	148
02	10	142	53	-	125	26	36	-	-	-	-	692	148
02	13	-	-	190	196	28	43	25	18	-	-	692	74
02	15	271	54	-	116	31	47	-	-	-	-	692	74
03	08	-	-	202	285	43	53	34	19	34	66	692	161
03	10	138	69	-	125	21	32	-	-	-	-	692	161
03	13	-	-	77	98	25	42	22	20	-	-	692	59
03	15	129	68	-	102	22	34	-	-	-	-	692	59
04	08	-	-	8,769	6,231	371	445	338	107	271	44	718	65
04	10	5,741	93	-	15,577	289	343	-	-	-	-	718	65
04	13	-	-	260	334	58	63	43	20	-	-	718	90
04	15(1)	401	196	-	463	35	52	-	-	-	-	718	90
05	08(1)	-	-	128	107	40	50	32	18	32	62	694	39
05	10(1)	120	50	-	129	31	35	-	-	-	-	694	39
05	13(1)	-	-	12,512	14,909	465	516	392	124	-	-	694	39
05	15	263	62	-	178	56	72	-	-	-	-	694	5
06	08	-	-	93	107	26	36	21	15	27	65	674	10
06	10	338	125	-	303	39	44	-	-	-	-	674	5
06	13	-	-	130	178	27	36	18	18	-	-	674	50
06	15	182	214	-	169	26	36	-	-	-	-	674	5
07	08	-	-	115	125	29	37	20	17	25	56	672	177
07	10	169	182	-	178	32	38	-	-	-	-	672	177
07	13	-	-	631	592	78	41	23	18	-	-	672	84
07	15	360	116	-	356	48	65	-	-	-	-	672	84
08	08	-	-	216	285	44	59	37	22	27	61	671	82
08	10	249	134	-	205	31	42	-	-	-	-	671	82
08	13	-	-	76	1,068	29	214	146	68	-	-	671	32
08	15	303	98	-	303	152	165	-	-	-	-	671	32
09	08	-	-	336	338	37	48	32	16	32	60	669	5
09	10	231	107	-	476	42	57	-	-	-	-	669	5
09	13	-	-	254	378	34	46	27	19	-	-	669	136
09	15	151	53	-	289	46	55	-	-	-	-	669	136
10	08	-	-	282	249	39	44	28	16	21	63	-	32
10	10	218	44	-	249	26	40	-	-	-	-	-	32
10	13	-	-	96	107	31	38	23	15	-	-	-	113
10	15	187	48	-	209	26	37	-	-	-	-	-	113
Minimum		120	44	76	98	17	31	18	15	21	44	669	5
Maximum		5,741	214	12,512	15,577	465	516	392	124	271	66	737	177

(1) Flotation chemical was not being added because the pump was not functioning properly.
(2) Based on well test data.

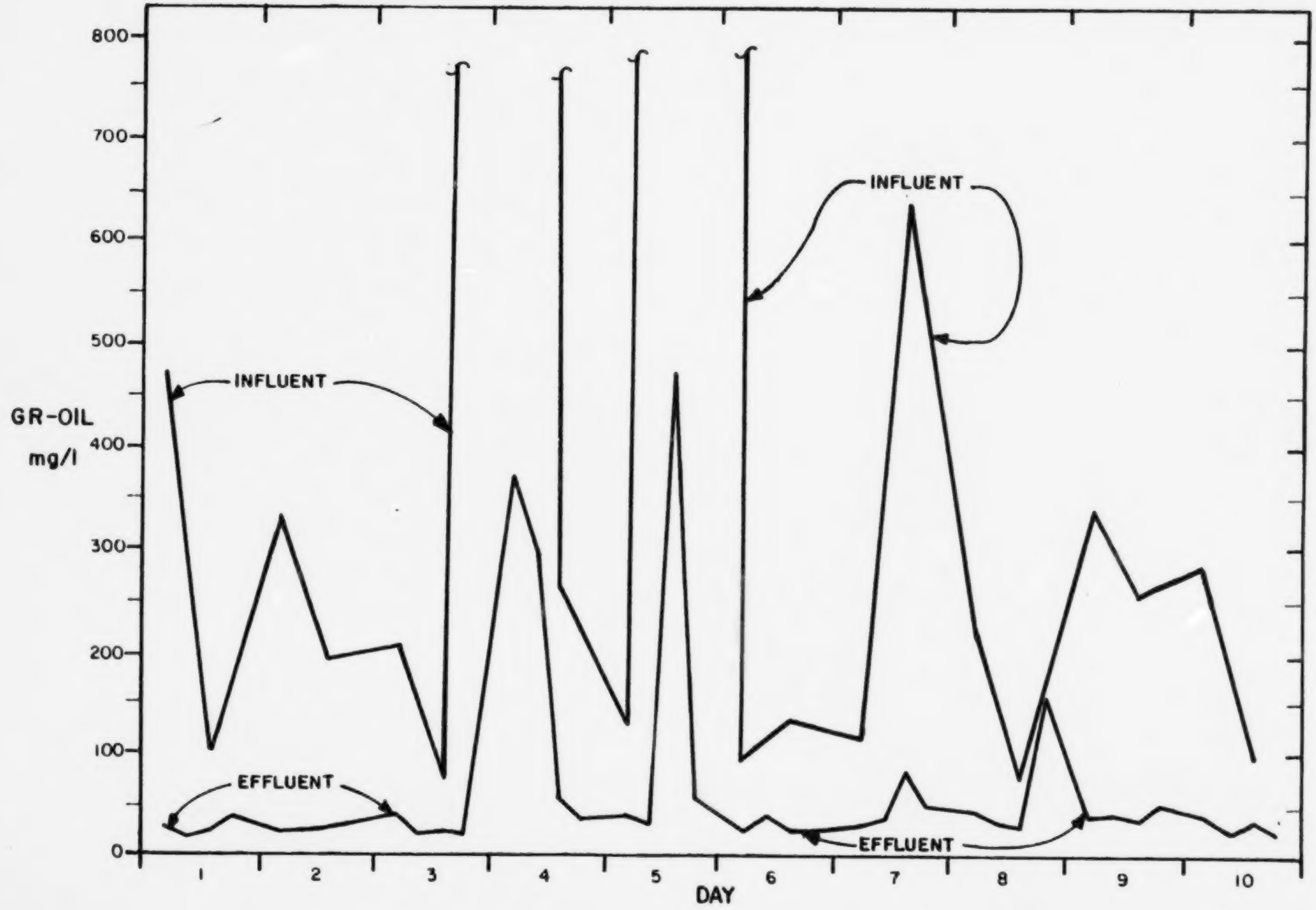


Figure 21. WD45C flotation unit performance, GR-oil vs time.

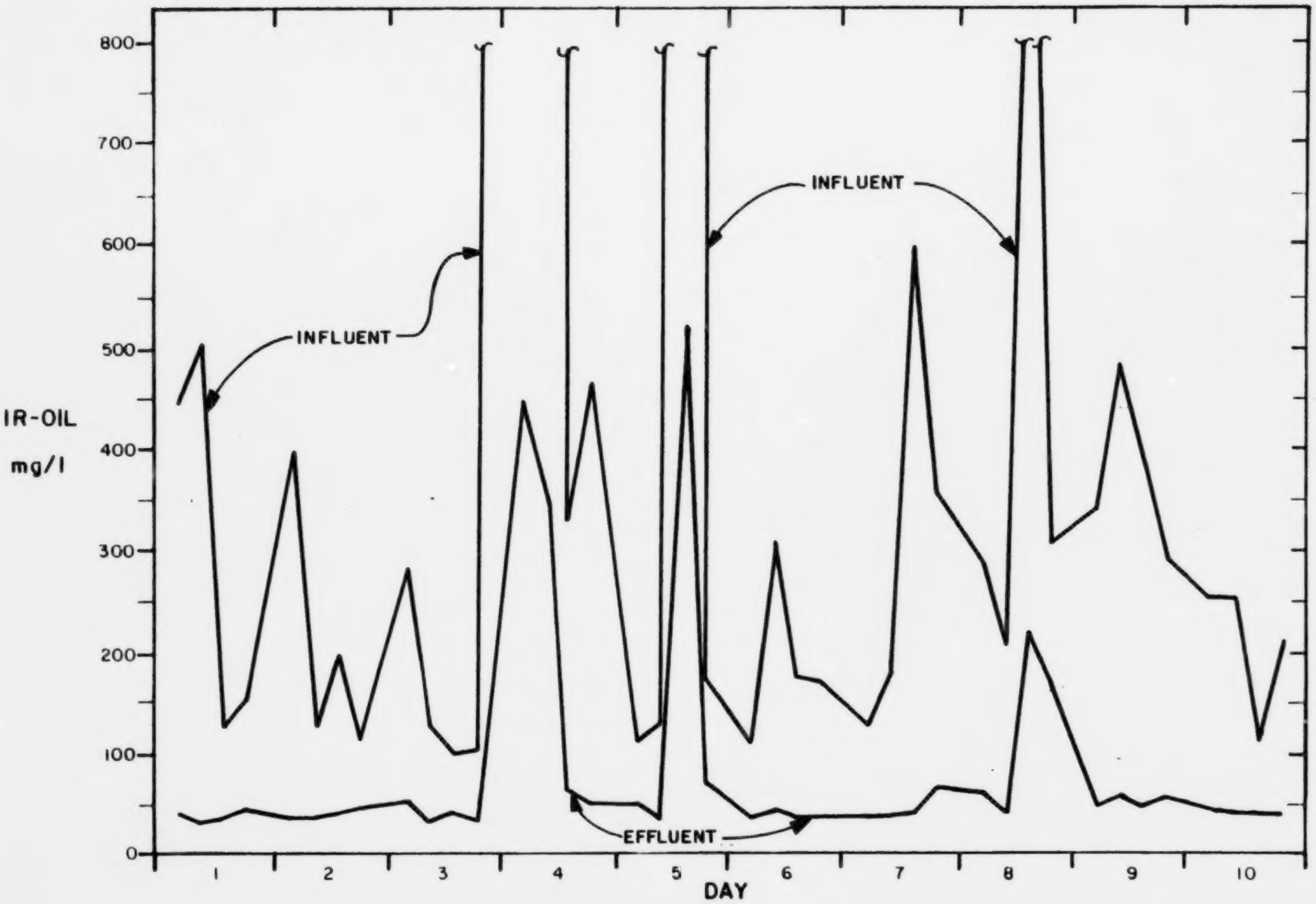


Figure 22. WD45C flotation unit performance, IR-oil vs time.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

pumped to the "A" gun barrel at 1100 hours. However, the amount would have been small and should have been flushed through the system by the 1300 hour sampling time.

The third effluent oil content peak occurred on Day 8. It corresponded with about one cubic meter of calcium bromide packing fluid flowing from Well B11D to the "A" gun barrel.

Flotation unit effluent oil content histograms are presented in Figure 23 and Figure 24. Figure 25 is a regression plot of effluent GR-Oil versus IR-Oil. A summary comparison of effluent oil content by the two methods is presented in Table 41.

The histograms indicate a similar frequency distribution for the two test methods. The regression plot and correlation coefficient indicate a significant correlation for the two test methods. However, the standard deviation for differences in paired tests of 30 mg/l is quite high.

As shown in Table 41, the IR-Oil mean is 81 mg/l, or 18 mg/l higher than the GR-Oil mean. Only one gravimetric test result exceeds the paired IR-Oil test result. The samples for the tests by the two methods were taken about one minute apart from a flowing stream. Differences in paired tests include sampling and testing variability.

The four GR-Oil values and five IR-Oil values over 100 mg/l have a strong influence on the mean oil content by both test methods, and also a strong influence in establishing the standard deviations.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 40. A summary of these test results is presented in Table 42.

On average, 31 percent of the oil in the effluent was soluble oil and 69 percent was dispersed oil.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 26. Extrapolation of the linear regression lines to zero dispersed oil indicates a residual IR-Oil of 10 mg/l and a residual GR-Oil of 1 mg/l would still be present in the brine after all dispersed oil is removed. The lowest soluble oil test result during the survey was 15 mg/l out of a total of 20 tests. In this case, extrapolation of the linear regression lines to zero dispersed oil may indicate a lower dispersed oil content than can actually be obtained.

Surface Tension

All surface tension test results are reported in Table 40. The mean surface tension of the flotation effluent is 60 dynes/cm.

Nine of the ten flotation effluent surface tension test results were in the range of 56 to 66 dynes/cm. The other result was 44 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

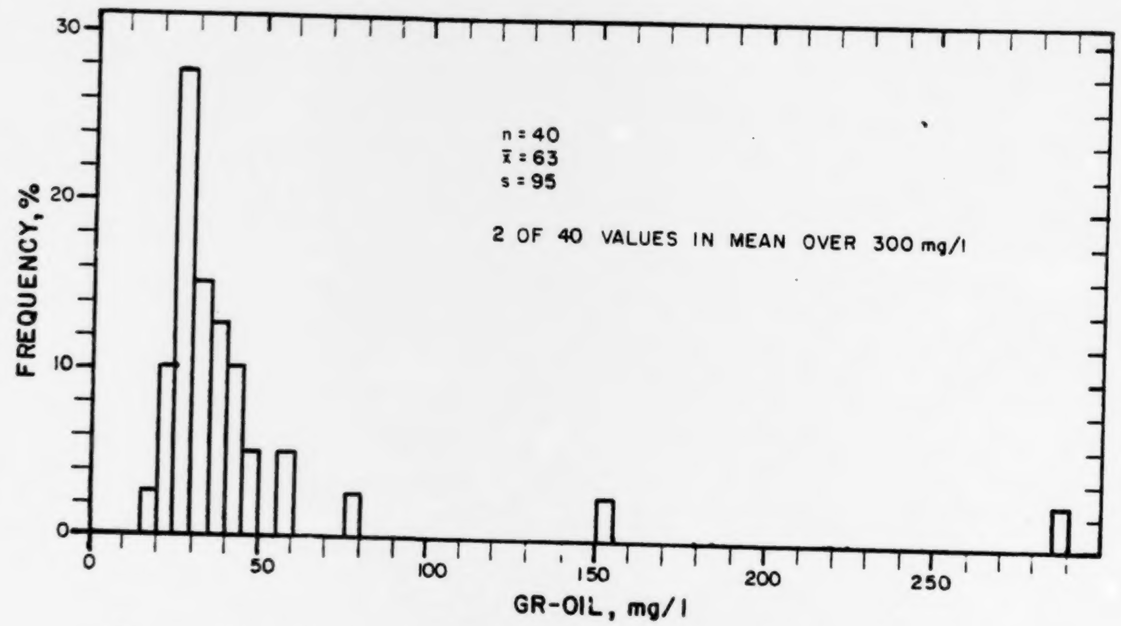


Figure 23. WD45C flotation unit effluent, GR-oil histogram.

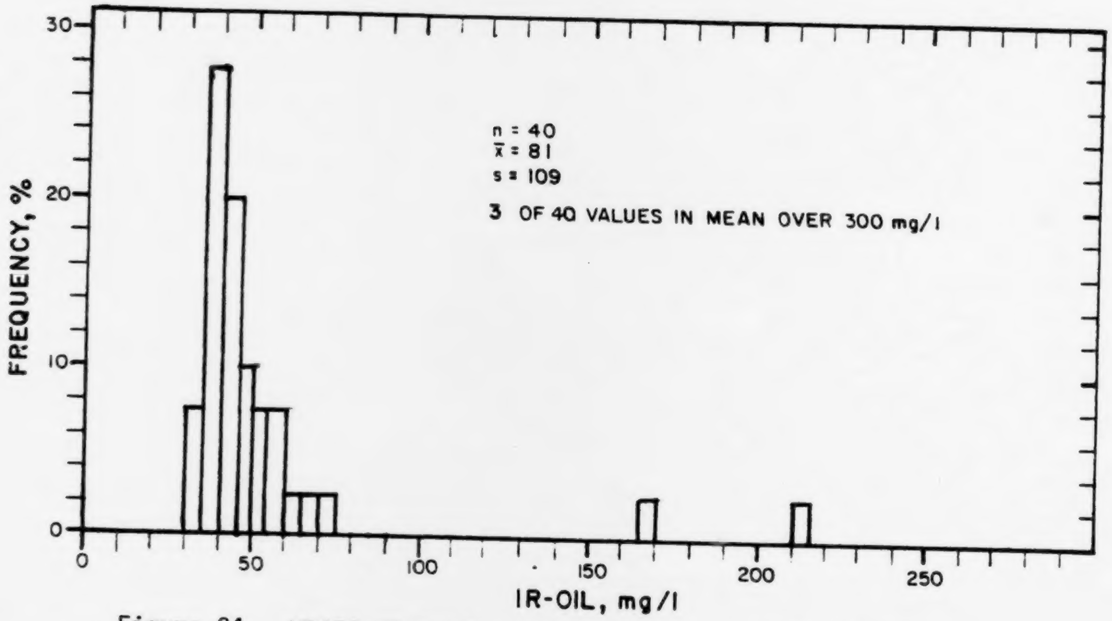


Figure 24. WD45C flotation unit effluent, IR-oil histogram.

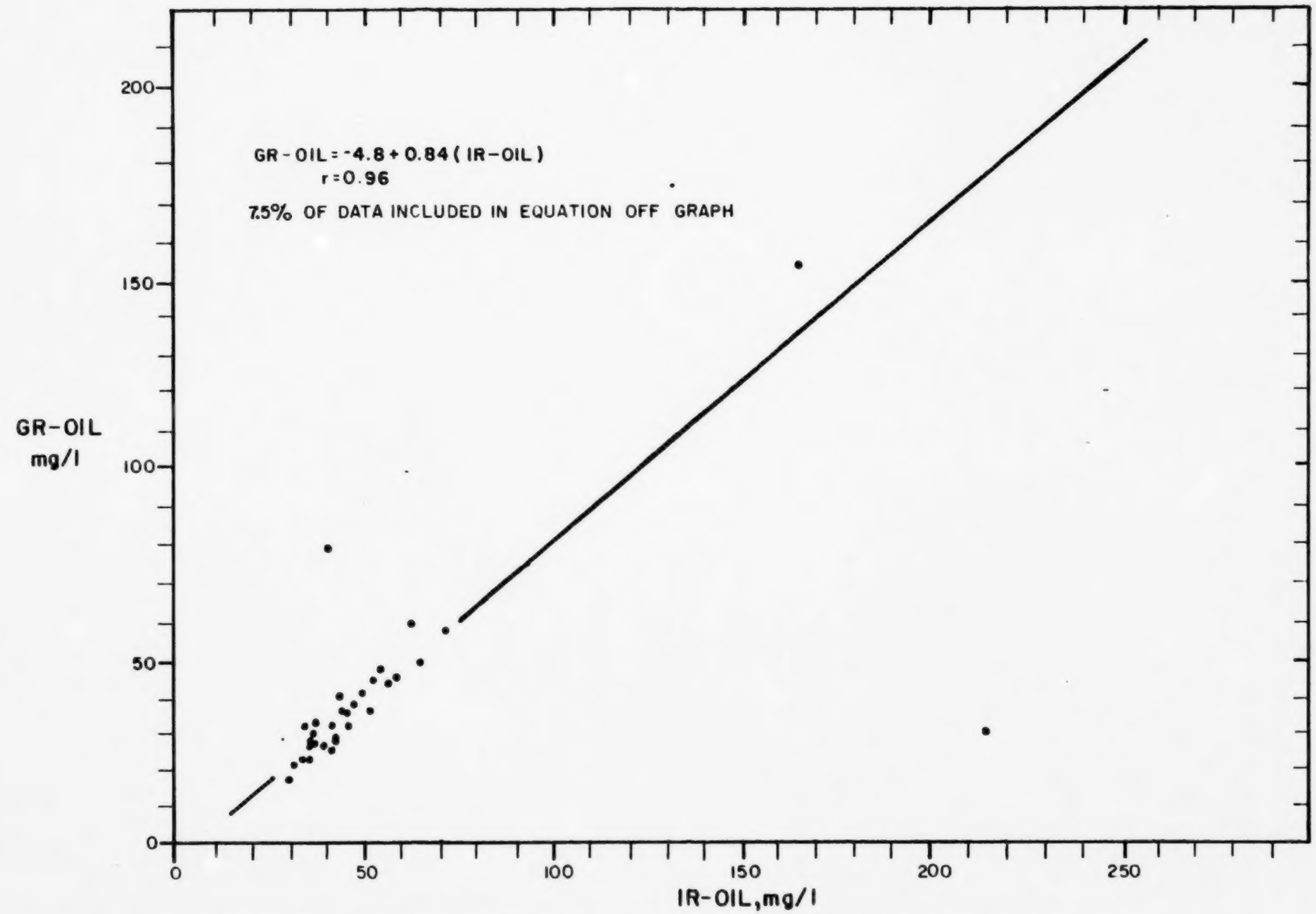


Figure 25. WD45C flotation unit effluent, infrared-gravimetric regression.

TABLE 41. WD45C FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	40	40
Mean, ($\bar{x}$), mg/l	63	81
Minimum, mg/l	17	31
Maximum, mg/l	465	516
Standard Deviation,(s), mg/l	95	109
	Paired Tests	
Number, (n)	40	
Mean of Differences, ($\bar{\Delta}$), mg/l	20	
Standard Deviation,(s_Δ), mg/l	30	

TABLE 42. WD45C SOLUBLE OIL SUMMARY

	Flotation effluent		Proportion
Analysis or test	Range mg/l	Mean mg/l	of total, percent
IR-Oil	35-516	96	100
Dispersed Oil	18-392	66	69
Soluble Oil	15-124	30	31

Note: Table includes only IR-Oil tests when an IR-Oil w/Silica Gel test was run.

$$\text{IR-Oil} = 1{,}147 - 17.8\ (\text{Surface Tension})$$
$$r = 0.87$$

The calculated regression equation indicates a rapid decrease in IR-Oil as surface tension increases.

Suspended Solids

Suspended solids test data are presented in Table 43 for major sampling points. A suspended solids summary for WD45C is presented in Table 44.

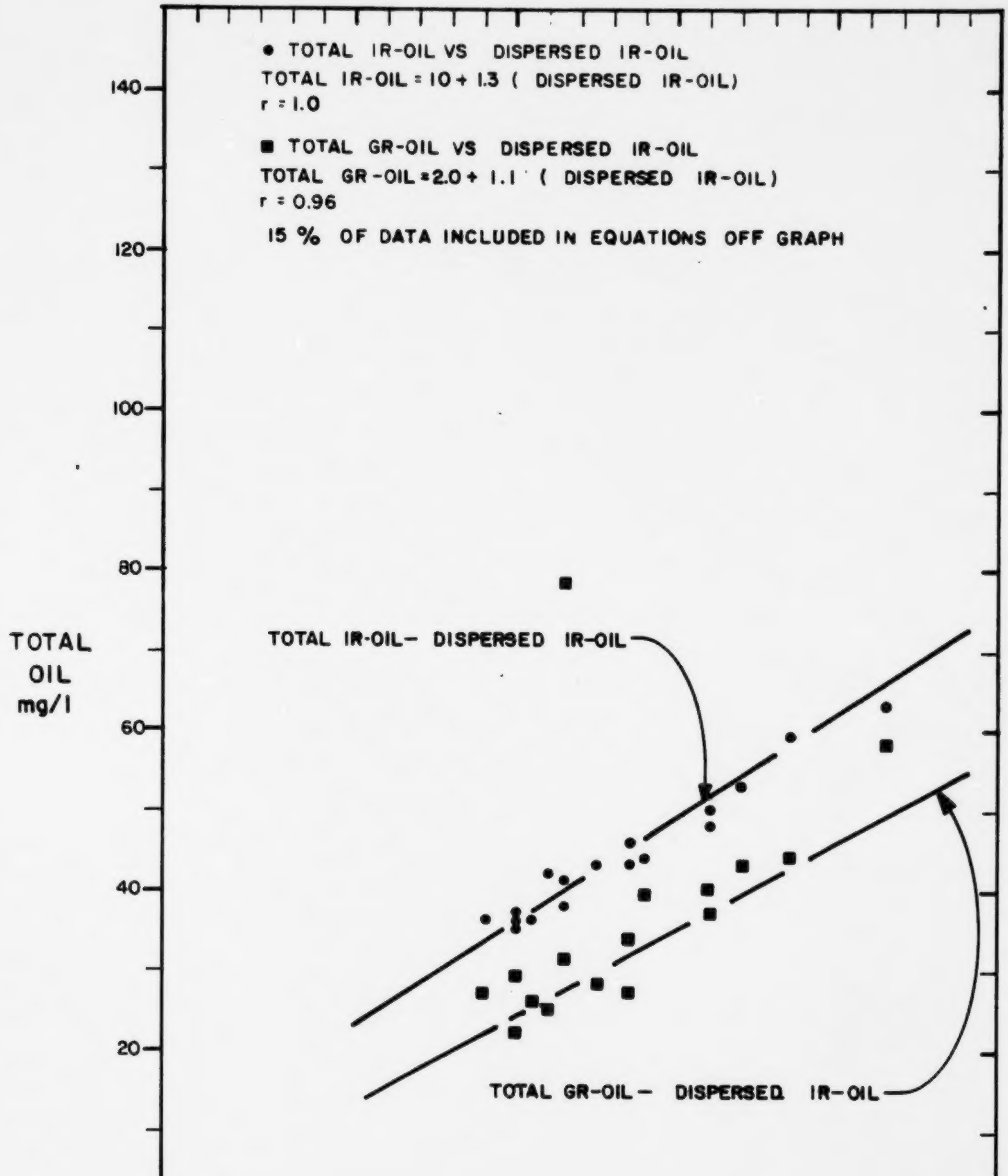


Figure 26. WD45C flotation unit effluent, total oil - dispersed oil regression.

TABLE 43. WD45C SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8--i)					Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	15	-	-	-	-	-	102	86	16	9	7	38	20	18	16	2
02	15	-	-	-	-	-	100	74	25	4	21	43	22	21	17	4
03	15	-	-	-	-	-	133	114	19	11	8	68	45	23	18	4
04	15	-	-	-	-	-	83	69	14	7	7	60	34	26	23	4
05	15	-	-	-	-	-	96	76	20	8	12	72	45	26	21	5
06	15	-	-	-	-	-	135	55	80	14	66	213	148	65	42	23
07	15	-	-	-	-	-	233	54	179	16	163	117	21	96	28	68
08	15	-	-	-	-	-	211	160	51	28	23	116	89	27	21	6
09	15	-	-	-	-	-	144	106	38	10	28	56	31	26	13	13
10	15	-	-	-	-	-	73	49	24	7	17	136	110	26	21	5
Minimum		-	-	-	-	-	73	49	14	4	7	38	20	18	13	2
Maximum		-	-	-	-	-	233	160	179	28	163	213	148	96	42	68

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

TABLE 44. WD45C SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l	
	9--i	9--0
Total	131	92
Freon Soluble	84	57
Freon Insoluble	47	35
Acid Soluble	11	22
Fixed	35	13

More than half of the solids are Freon soluble. Except for acid soluble solids, the other solids decrease across the flotation unit.

Figure 27 presents time-indexed plots of Freon insoluble suspended solids in the flotation influent and effluent, and of flotation effluent dispersed oil. The suspended solids samples were taken at 1500 each day and the dispersed oil samples were taken at 0800 and 1300 each day.

77

The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when flotation influent or effluent suspended solids are higher. The lack of a readily apparent relationship may be because the samples were not all taken at the same time and also because of the substantial variability of the suspended solids test.

Filtered Brine

The filtered brine IR-Oil content of WD45C effluent was in the range of 21 to 271 mg/l with a mean of 53 mg/l. The mean IR-Oil content of unfiltered brine on WD45C was 85 mg/l for samples when filtered brine tests were also run. The oil content of the filtered brine is lower than that of the unfiltered brine as expected. However, as discussed in Section 5, there is a bias of an unknown amount with certain brines which limits the confidence that can be placed in the test.

Flotation Unit Performance

Figure 28 is a regression plot of IR-Oil in and out of the flotation unit. Flotation effluent IR-Oil content increases gradually as influent IR-Oil content increases. The slope of the regression line is only 0.028.

Thirty-six of forty flotation influent IR-Oil test results are in the range from 98 to 592 mg/l. The other four test results are from 1,068 to 15,577 mg/l. High effluent oil contents occurred at the same time as the four high influent oil contents. This is illustrated in Table 45.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

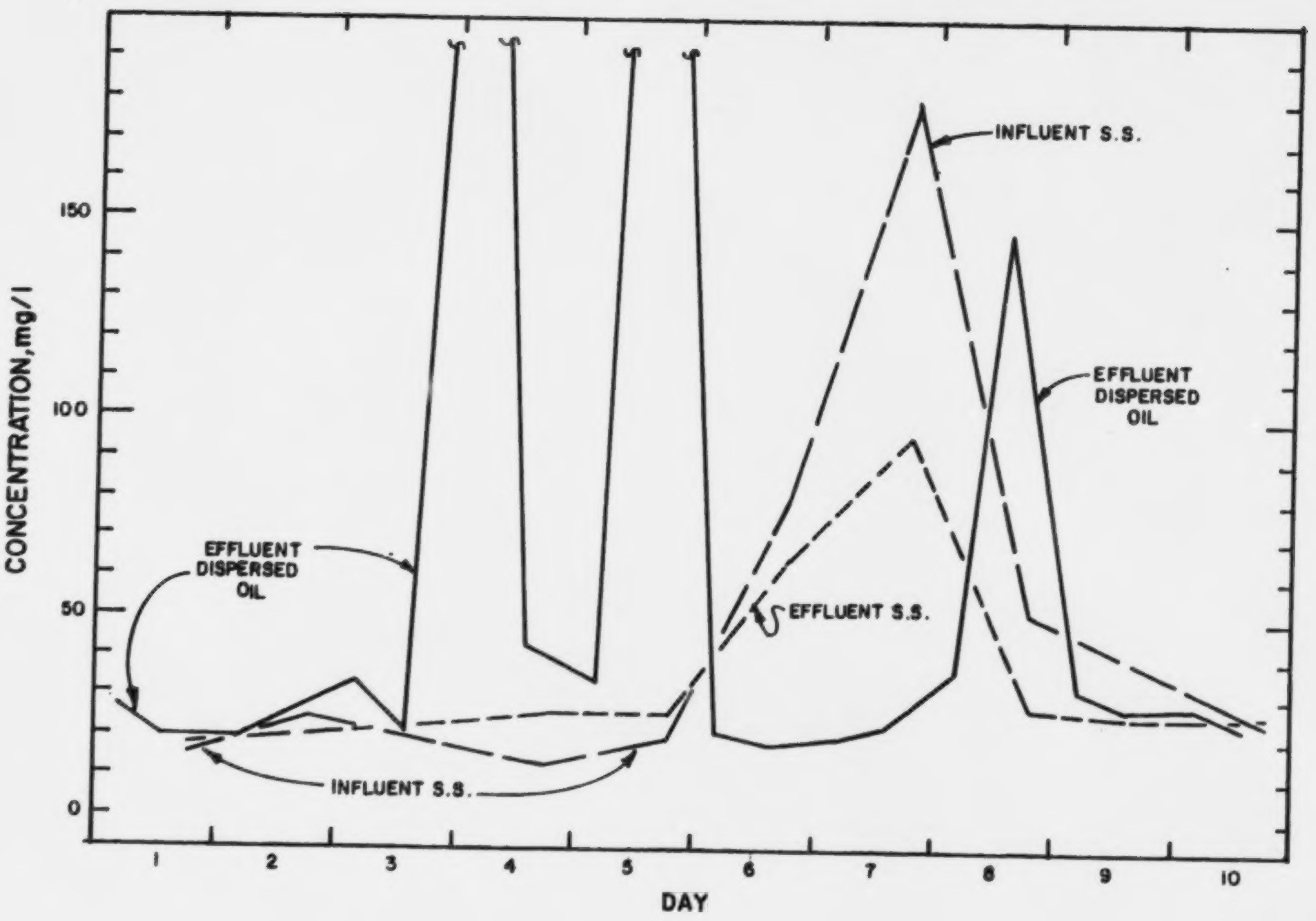


Figure 27. WD45C flotation unit Freon insoluble suspended solids.

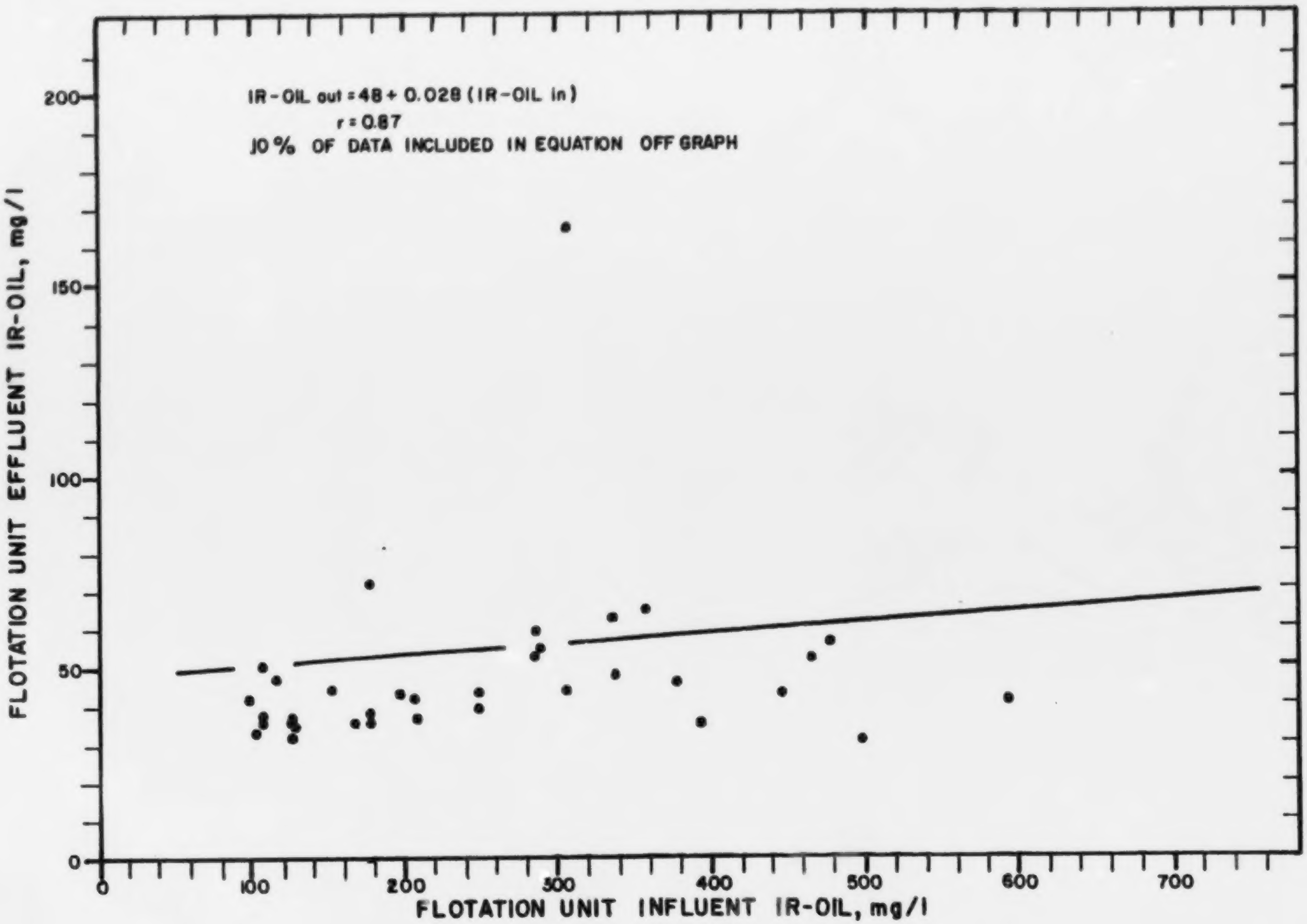


Figure 28. WD45C flotation unit in-out IR-oil regression.

TABLE 45. WD45C IR-OIL CONTENT SUMMARY

Sample time Day	Hour	Flotation unit IR-Oil, mg/l Influent	Effluent
Four High Test Results			
04	08	6,231	445
04	10	15,557	343
05	13	14,909	516
08	13	1,068	214
Mean		9,441	380
Other Thirty-Six Test Results			
Mean		249	48
Minimum		98	31
Maximum		592	65,(63,72,165)(1)

(1) The samples for the three values in ( ) were taken 2 hours after one of the four high values. The flotation unit operation may not have had time to stabilize.

When all flotation unit influent and effluent oil content test results are considered, both the exceptionally high and the low, there is a clear indication that a consistent flotation influent would result in a more consistent effluent.

Gun Barrel Performance

Twenty IR-Oil tests were run on the effluent of each gun barrel. Forty IR-Oil and forty GR-Oil tests were run on the combined effluent of the two gun barrels which is also the flotation unit influent. All test results are listed in Table 40.

The "B" gun barrel IR-Oil content averaged 96 mg/l. Over one-half of the values were less than 100 mg/l, and only one exceeded 200 mg/l. This gun barrel did not receive flotation froth recycle or any intermittent flows, aside from variations in well flow rates.

The average effluent IR-Oil of the "A" gun barrel was 516 mg/l. The "A" gun barrel received froth recycle and other intermittent flows as described earlier.

The IR-Oil content for the combined stream from the two gun barrels averaged 1,169 mg/l. The IR-Oil content of four samples was over 1,000 mg/l. The GR-Oil content of the combined stream averaged 1,263 mg/l. The lines labeled "influent" in Figure 21 and Figure 22 illustrate the variability in oil content of the combined stream from the gun barrels.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

The results of three susceptibility to separation tests on the combined flow from the two gun barrels are presented in Table 46. The tests indicate oil is readily separated from the brine on WD45C. After five minutes of static settling under test conditions, the mean IR-Oil content of the brine was 59 mg/l. This is a lower oil content than was accomplished by the gun barrels. A graphical settling rate comparison with samples from other platforms is presented in Section 17.

TABLE 46. WD45C COMBINED GUN BARRELS EFFLUENT SUSCEPTIBILITY TO SEPARATION

Sampling time	Test number 1	Test number 2	Test number 3	Mean
Day	3	5	7	-
Hour	10	10	10	-
Minute	51	40	36	-
Settling time, minutes	**IR-Oil, mg/l**			
0-1 (1)	69	88	89	82
5	55	68	55	59
15	56	61	53	57
30	54	58	62	58
60	49	85	71	68
120	49	53	61	54

(1) The actual settling time is the time required to handle the separatory funnel after filling and to draw a sample, and is estimated at not more than one minute.

Miscellaneous Brine Tests

All other brine test results for WD45C are listed in Tables 47, 48, 49, and 50. The results for the following tests were in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content on WD45C. These parameters will be discussed with respect to variations between platforms in Section 17.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on WD45C. These tests also are only significant with respect to comparisons between platforms.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE O TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTION HERE

TABLE 47. WD45C SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °C						pH	Specific gravity[(1)]
Day	Hour	13--0	8A-1	8A-0	8B-0	9--i	9--0	9--0	9--0
01	08	-	-	-	-	-	38.2	-	1.070
01	10	39.0	45.0	39.7	39.2	39.4	39.4	7.0	-
02	08	-	-	-	-	-	38.7	-	1.070
02	10	39.5	46.0	40.7	39.0	41.0	40.2	7.0	-
03	08	-	-	-	-	-	39.4	-	1.075
03	10	40.0	40.4	40.6	40.0	40.6	40.6	7.0	-
04	08	-	-	-	-	-	37.5	-	1.071
04	10	39.5	40.5	40.1	39.6	39.5	46.0	7.0	-
05	08	-	-	-	-	-	39.0	-	1.075
05	10	39.7	42.2	40.5	39.7	40.2	40.4	7.0	-
06	08	-	-	-	-	-	36.8	-	1.072
06	10	38.0	34.0	38.0	39.0	37.7	38.2	7.0	-
07	08	-	-	-	-	-	38.2	-	1.072
07	10	38.6	37.2	40.0	39.2	39.9	39.7	7.0	-
08	08	-	-	-	-	-	39.0	-	1.075
08	10	40.1	40.4	41.3	40.0	41.0	40.7	7.0	-
09	08	-	-	-	-	-	40.2	-	1.073
09	10	41.2	51.5	41.8	40.6	41.5	41.7	6.9	-
10	08	-	-	-	-	-	38.7	-	1.072
10	10	40.5	46.4	41.3	39.7	41.2	40.7	7.0	-
Mean		40.0	42.4	40.4	39.6	40.2	39.7	7.0	1.073
Minimum		38.0	34.0	38.0	39.0	37.7	36.8	6.9	1.070
Maximum		41.2	51.5	41.8	40.6	41.5	46.0	7.0	1.075

Note: Sample point identification numbers as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in the table above.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
8-1/2"

TABLE 48. WD45C SULFATE REDUCING BACTERIA

Sample point	Bacteria per milliliter Sample No. 1	Bacteria per milliliter Sample No. 2
Flotation Unit - Out (9--0)	10-100	10-100
Flotation Unit - In (9--i)	1-10	10-100
LP Separator "A" - Out (5A10)	0	0
Skim Pile - Out (13--0)	1-10	0

Sample Day and Hour: 06 at 19

TABLE 49. WD45C WATER CUT AT VARIOUS SAMPLE POINTS

Sample time Day	Sample time Hour	Water cut, % Gun barrel "A" in	Water cut, % Skim pile out	Water cut, % Flare scrubber
01	10	73	-	-
02	10	81	-	-
03	10	74	-	-
04	10	84	100	-
05	10	76	-	-
06	10	84	-	1
07	10	91	-	-
08	10	80	-	-
09	10	83	-	1
10	10	60	-	-
Mean		79	-	-
Minimum		60	-	-
Maximum		91	-	-

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 50. WD45C IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	75,000
Calcium (Ca)	6,100
Magnesium (Mg)	1,020
Barium (Ba)	1,100
Chloride (Cl)	37,340
Sulfate (SO_4)	170
Alkalinity (as HCO_3)	342
Iron (Total)	7
Sulfide (as H_2S)	0.68
Total Dissolved Solids	
Summation	121,000
Gravimetric	80,500

Sample Day and Hour: 07 at 08

Crude Oil Tests

All crude oil test results are listed in Tables 51 and 52. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one or two and are of primary significance for comparisons between platforms. Two equilibration tests were run.

The limited number of tests run on crude oil provided only a limited characterization of the crude oil. Between-platform comparisons will be presented in Section 17.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 51. WD45C CRUDE OIL MISCELLANEOUS TESTS

Sample time Day	Sample time Hour	Temperature °C	Specific gravity(2)	Surface tension(2) dynes/cm
01	08	36.0	0.888	29
02	08	34.2	0.892	29
03	08	38.5	0.895	31
04	08	36.2	0.903	31
05	08	37.5	0.888	31
06	08	35.7	0.886	29
07	08	37.6	0.884	29
08	08	37.2	0.886	31
09	08	38.8	0.889	31
10	08	37.0	0.889	31
Mean		36.9	0.890	30
Minimum		34.2	0.884	29
Maximum		38.8	0.903	31

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
02	08	22.66	20.21

	Equilibration at 82°C Brine TDS = 100,000 mg/l	
	Test No. 1	Test No. 2
Oil/Water Ratio	4/1	4/1
IR-Oil, mg/l	137	125

---

(1) Samples taken from LACT unit.
(2) Reported for approximately the temperature in table.

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 52. WD45C CRUDE OIL BOILING RANGE DISTRIBUTION

	Run No. 1	Run No. 2	Mean
Initial Boiling Point, °C	150	150	150
Final Boiling Point, °C	490	480	485
Boiling range, °C	Percent recovered		
Below - 200	31.7	27.7	29.7
200 - 250	12.0	12.8	12.4
250 - 300	21.8	22.0	21.9
300 - 350	20.2	22.1	21.2
350 - 400	5.8	6.7	6.2
400 - 450	7.4	6.2	6.8
450 - 500	0.8	2.1	1.4
500 - 550	0.4	0.3	0.4
Total	100.1	99.9	100.0

Sample Day and Hour: 02 at 08

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

SECTION 8

PLATFORM ST177

GENERAL

A nine-day test program was conducted on Platform ST177 from July 13 through July 21, 1979. The test program was sandwiched in between two hurricanes.

The survey team members arrived at the platform on July 9 and set up the test equipment the next morning. Before noon on July 10, evacuation of the platform was ordered because of the approach of Hurricane Bob. The team members repacked the equipment and left the platform that afternoon.

The survey team returned to the platform on July 11 and set up the equipment on July 12. The wells which had been shut in during the hurricane were brought back in production on July 12. The test program started on July 13.

As an aftermath of Hurricane Bob, the production operations were upset the first six days of the test program. This is reflected in the test results. The last three days' operations were relatively stable.

The test program was curtailed after nine days because of the approach of another hurricane.

A Company engineer was available in the field to assist the survey team, and the operating company provided all facilities and information needed for a successful program.

FACILITIES AND OPERATIONS

Production From Wells

Twenty-four wells were in production during the entire test program, and three other wells were in production for a minimum of four days.

All wells flowed to either a high-pressure separator, or a low-pressure separator. None of the production was gas lifted. The daily production for the nine-day period calculated from well test data averaged 874 m^3/d (5,496 bpd) of oil, 763 m^3/d (4,798 bpd) of water, and 504,617 std m^3/d (17,831 Mcfd) of gas. The calculated water cut was 47 percent. There were minor variations in water cut depending on which wells were in production.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

The metered oil production for the nine-day period was 895 m^3/d (5,632 bpd) or 2.5 percent more than the calculated production.

Production Process System

The flow of oil and water through the system is shown in Figure 29. Design and operating data on major vessels are shown in Table 53. Twelve wells flowed to a high-pressure two-phase separator with the liquids then flowing to the low-pressure three-phase separator.

Fifteen wells flowed directly to the low-pressure separator. The crude oil flowed from this separator to a run tank, and the water flowed to the gun barrel.

Miscellaneous open and closed drains discharged to sumps from which the liquids received were pumped to the gun barrel. Also, water or oil could be pumped from the run tank to the gun barrel without first draining to a sump.

Figure 30 is a flow schematic for the water streams to and from the gun barrel and flotation unit. A nominal average water flow balance is presented in the figure.

Estimated short-duration maximum flow rates were: froth from the flotation unit, 220 m^3/d; from the run tank, 360 m^3/d; and from Sump 14A, 330 m^3/d.

9-1/8"

A flotation aid, Tretolite FR-81, was added to the effluent of the gun barrel.

The gun barrel received primarily oily water and provided for gravity oil separation to prepare the water for flotation. At times, the oil content of the gun barrel inlet was quite high because of various upsets that will be described later.

The gun barrel was a large rectangular vessel. Figure 31 is a dimensional sketch of the gun barrel, also showing potential flow patterns.

The inlet distributor is located about one foot above the bottom of the tank. It is a cylinder with slots around the sides. The outlet is on the tank wall near the bottom. The inlet distributor reduces the inlet flow velocity and directs the flow equally around the sides. However, there is significant potential for short circuiting to the outlet. A standard calculation procedure is not available to estimate the theoretical separation capability of a gravity separator with the configuration of the ST177 gun barrel.

The polishing unit is a proprietary four-cell dispersed gas unit as depicted in Figure 32 (Wemco Nozzle Air, Model 66). The flotation unit is very similar to the one described in Section 6 except that recycled water is used to educt gas into the water.

The design flow for the unit was 2,457 m^3/d (15,450 bpd). The average

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

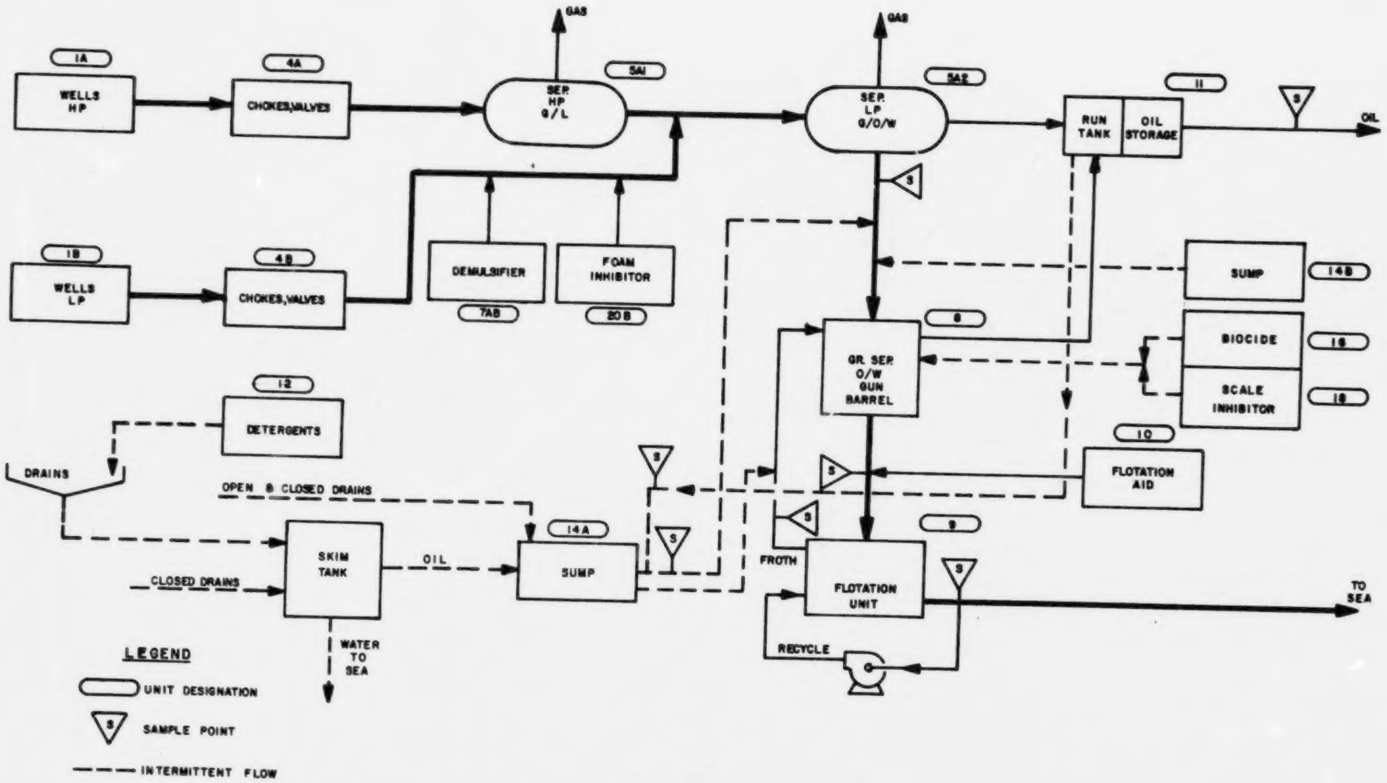
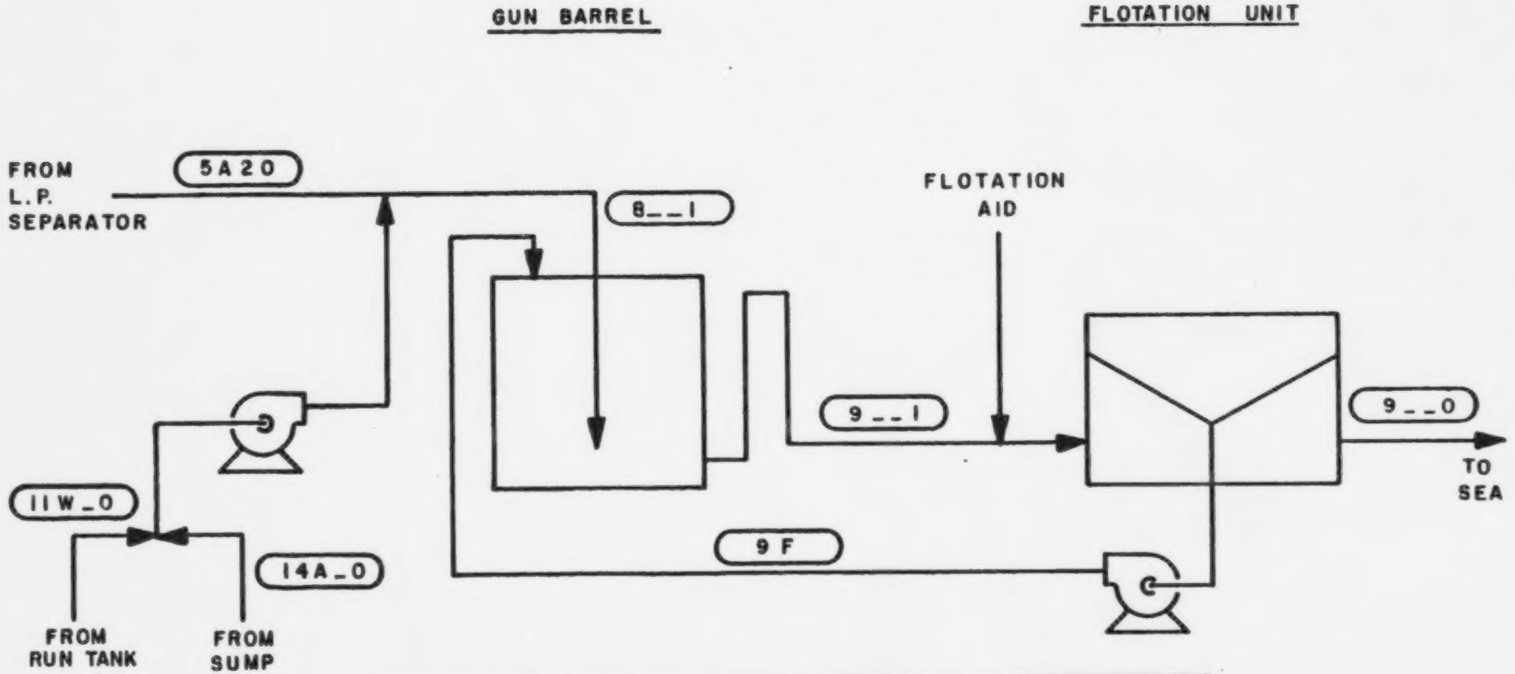

1A
WELLS HP
4A
CHOKES,VALVES
GAS
SEP. HP G/L
5A1
GAS
SEP. LP G/O/W
5A2
11
RUN TANK
OIL STORAGE
S
OIL
1B
WELLS LP
4B
CHOKES,VALVES
DEMULSIFIER
7AB
FOAM INHIBITOR
20B
S
SUMP
14B
8
GR. SEP. O/W GUN BARREL
BIOCIDE
16
SCALE INHIBITOR
18
12
DETERGENTS
DRAINS
OPEN & CLOSED DRAINS
S
S
10
FLOTATION AID
S
FROTH
9
14A
SUMP
S
SKIM TANK
OIL
CLOSED DRAINS
WATER TO SEA
FLOTATION UNIT
S
TO SEA
RECYCLE
LEGEND
UNIT DESIGNATION
SAMPLE POINT
INTERMITTENT FLOW

Figure 29. Flow diagram, production process system, ST177.

TABLE 53. ST177 VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 5A1 High pressure 2-phase separator	 5A2 Low pressure 3-phase separator	 8 Gravity separator gun barrel	 9 Flotation unit, hydraulic, dispersed gas
Trade Name or Vessel Type	Horizontal Cylinder	Horizontal Cylinder	Rectangular	Wemco Model 66
Design Parameters				
Dimensions, m (ft)				
Diameter, O.D.	-	1.8(6)	-	-
Length, S.S.	-	6.1(20)	-	-
Length	-	-	6.86(22.5)	6.6(21.8)$^{(1)}$
Width	-	-	4.27(14)	1.7(5.5)$^{(1)}$
Height	-	-	6.15(20.2)	-
Separation Surface Area, m^2 (ft^2)				
Total	-	-	29.3(315)	11.2(120)
Per Cell	-	-		2.8(30)
Volume, m^3 (bbl)				
Total	-	-	170(1070)	6.8(43)
Oil Phase	-	-	54(340)	
Water Phase	-	-	116(730)	
Number of Cells	-	-	-	4
Flow Rate, m^3/day (bpd)	-	-	-	2460(15450)
Overflow Rate Per Cell, $(m^3/d)/m^2$, $(bpd/ft^2)^{(3)}$	-	-	-	880(515)
Recycle Rate, Percent of Flow	-	-	-	-
Retention Time, min.	-	-	-	4
Average Operating Parameters				
Temperature, $^{o}C(^{o}F)$	-	37.1(98.8)	36.6(97.9)	36.1(97.0)
Pressure, kPag, (psig)	7190(1040)	590(85)	-	-
Flow Rate, m^3/d $(bpd)^{(2)}$	-	-	919(5,778)	849(5,338)
Flow Rate, Percent of Design	-	-	-	35
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)	-	-	31(18)	300(180)
Recycle Rate, Percent of Flow	-	-	-	510
Froth Flow, Percent of Flow	-	-	-	8

(1) Separation area.
(2) Effluent flow.
(3) Overflow rate is surface area divided by flow rate.


GUN BARREL
FLOTATION UNIT
FROM L.P. SEPARATOR
5A20
8__I
FLOTATION AID
9__I
9__0
TO SEA
11W_0
14A_0
9F
FROM RUN TANK
FROM SUMP

FLOW		5A20	11W-0	14A-0	9F	8__I	9__I	9__0
	m³/d	763	78	8	70	919	919	849
	bpd	4798	490	50	440	5778	5778	5338

Figure 30. ST177 water handling system flow schematic.

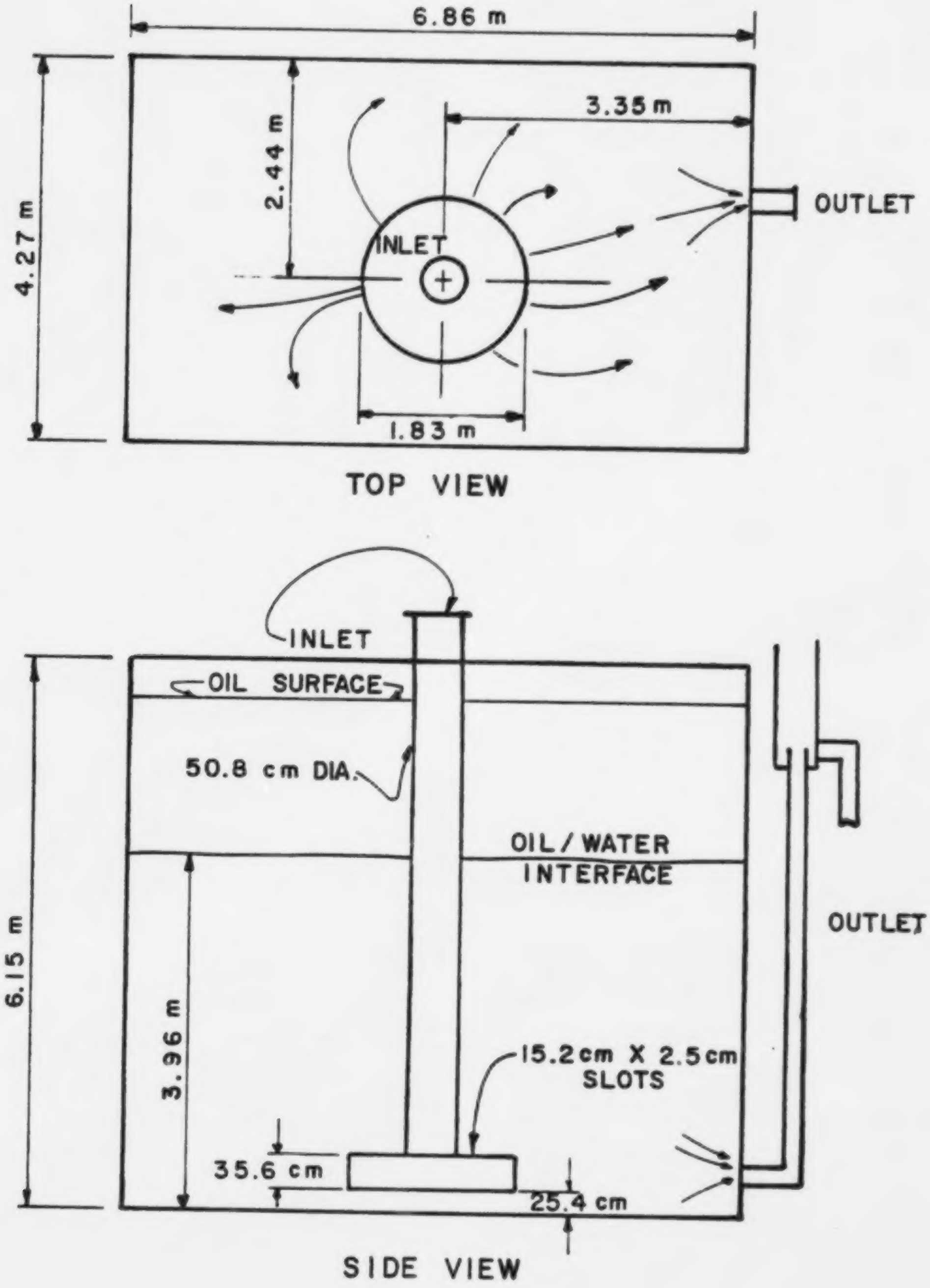

6.86 m
4.27 m
2.44 m
3.35 m
OUTLET
INLET
1.83 m
TOP VIEW
INLET
OIL SURFACE
50.8 cm DIA.
OIL / WATER INTERFACE
OUTLET
6.15 m
3.96 m
15.2 cm X 2.5 cm SLOTS
35.6 cm
25.4 cm
SIDE VIEW

Figure 31. ST177 gun barrel sketch.

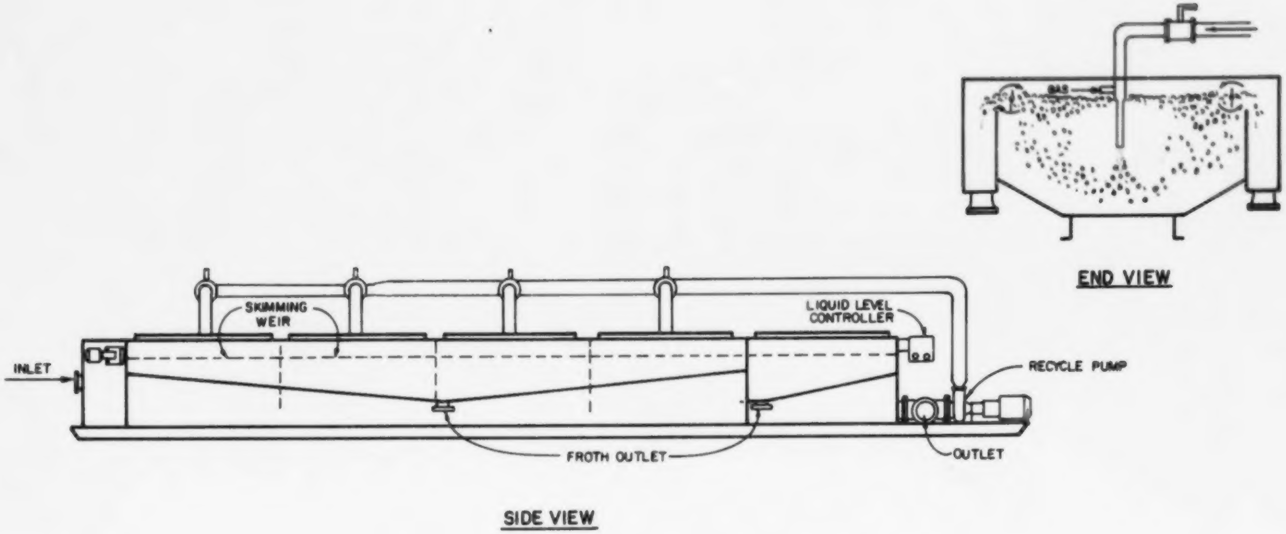

GAS
END VIEW
SKIMMING WEIR
LIQUID LEVEL CONTROLLER
INLET
RECYCLE PUMP
FROTH OUTLET
OUTLET
SIDE VIEW

Figure 32. ST177 flotation unit sketch.

operating flow based on effluent flow was 849 m^3/d (5,338 bpd) or 35 percent of design flow. The froth flow was 70 m^3/d (440 bpd) or 8 percent of forward flow. The recycle flow was 4,360 m^3/d (27,400 bpd) or 510 percent of the forward flow.

SITE SPECIFIC TEST PROGRAM

The planned test program for major brine samples is presented in Table 54. The number of samples to be taken in ten days and the time the samples were to be taken each day are listed. Only nine days of the planned program were completed because of a hurricane. A limited number of tests were run at minor sampling points not shown in Table 54.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operating conditions are reported in this subsection.

Flow Monitoring

No direct measurements of flow variability were accomplished on ST177. A service representative worked with the clamp-on flow monitor on the platform, but was unsuccessful. Therefore, all reported flow data are based on well test data or pump curves.

Well Test Data

The well test data provided by the operator are presented in Table 55. The data are grouped according to whether the flow was initially to the high-pressure separator or the low-pressure separator. The table shows which wells flowed intermittently.

As noted earlier, the measured oil production and the estimated oil production from well test data differed by only 2.5 percent. This lends confidence to estimated water flows.

Vessel Pressures and Temperatures

The pressure of each oil/water separation vessel was recorded twice per day. The temperature was recorded once per day based on the temperature of an effluent sample.

Table 56 presents pressure and temperature ranges for the nine-day period.

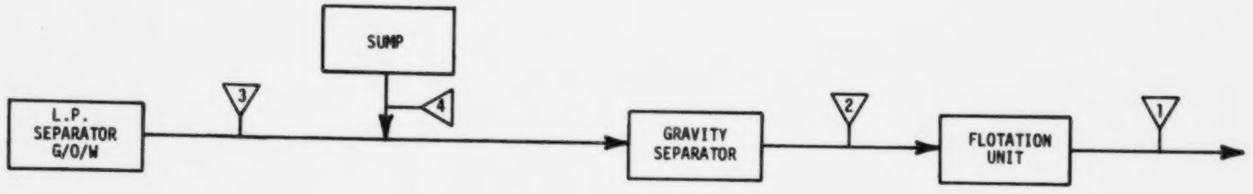


TABLE 54. ST177 TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS							
	1		2		3		4	
	9--0		9--1		5\20		14--0	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests								
Infrared Oil	40	8,10,13,15	40	8,10,13,15	20	8,13	-	-
Temperature	20	8,10	10	10	10	10	10	10
pH	10	10	-	-	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-	-	-
Water Surface Tension	10	8	-	-	-	-	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	-	-	-	-
IR-Oil Filtered Brine	10	8	-	-	-	-	-	-
Susceptibility to Separation	-	-	2	(1)	-	-	-	-
Laboratory Tests								
Gravimetric Oil	40	8,10,13,15	20	8,13	-	-	-	-
Suspended Solids	10	15	10	15	10	15	-	-
Ionic Analysis	1	(1)	-	-	-	-	-	-
Bacterial Culture	1	(1)	1	(1)	1	(1)	1	(1)
Particle Size Distribution	3	(1)	3	(1)	3	(1)	-	-
IR-Scan of Freon Extracts	1	-	-	-	-	-	-	-

(1) Field scheduled.

NOTE: Some of the samples were not scheduled for a certain hour and are listed at the time actually run. Time of tests listed is by military hour.

TABLE 55. ST177 WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bod	Water bod	Lift gas Mcfd	Pressure, psig SIBHP	Pressure, psig FTP	Choke Size 1/64 in.	API gravity	Days of production
Flowing to Low Pressure Separator											
A-1-	F-2-H	9,870	358	430	13	0	4,851	1,500	13	27.8	All
A-4-	G-4-G	11,318	62	3	314	0	5,664	850	11	36.1	All
A-4D	F-2-H	9,817	200	607	912	0	4,921	700	26	35.0	All
A-6-	F-2-H	9,857	120	89	1	0	4,218	350	14	36.5	All
B-3D	E---H	9,372	197	20	483	0	5,187	1,000	16	36.7	All
B-5D	F-2-H	9,373	625	612	32	0	5,038	1,400	16	37.7	All
B13A	A-5-F	7,236	104	22	73	0	3,650	250	24	33.7	All
B16-	G-8-E	11,370	151	7	185	0	5,485	375	19	35.6	All
C-1-	B-1--	7,428	-	0	0	0	3,200	-	-	34.9	All
C-4-	E---G	9,452	125	152	0	0	3,021	400	15	38.9	All
D-4-	S-3L1	10,613	142	12	845	0	5,074	500	22	39.2	All
D-8D	F-2BL	9,983	21	5	332	0	4,783	300	22	33.8	All
D10-	E---L	9,435	1,287	746	187	0	4,563	1,550	18	35.4	All
D13-	UN--P	10,536	64	12	111	0	4,890	320	21	34.7	3,7,8,9
E11-	G-8-J	11,733	148	215	9	0	-	700	30	38.4	All
Total (Average)		(9,826)	3,604	2,932	3,497	-	(4,610)	(728)	(19)	(35.6)	
Flowing to High Pressure Separator											
A-7-	F-2-H	9,483	482	908	3	0	4,841	1,750	19	37.3	All
B-8-	G16-H	13,131	1,345	345	1,036	0	8,584	3,700	16	34.9	1,2,3,6,7,8,9
B-9-	F-2-H	8,866	2,679	432	4	0	4,659	3,200	12	37.6	All
B-9D	D-2-H	7,859	943	15	0	0	3,107	2,550	15	37.6	All
B16D	G-2-E	10,964	456	185	554	0	7,253	1,500	9	36.1	All
E-5-	D-2-J	7,879	1,639	11	1	0	3,347	1,900	12	34.9	All
E-7-	G16-J	12,652	1,619	47	1	0	5,336	3,300	8	44.6	All
E-7D	G20-J	12,940	639	70	2	0	5,497	2,700	9	37.0	All
E-9-	G16-J	12,842	3,440	47	1	0	4,484	3,500	16	38.8	All
E12-	G16-C	11,535	727	24	0	0	-	3,400	8	51.2	All
E12D	G10-C	11,113	362	288	0	0	-	4,450	7	34.4	All
UC1-	F-2-H	9,192	414	508	5	0	4,812	1,850	12	35.7	3,4,5,6,8
Total (Average)		(10,705)	14,745	2,880	1,607	-	(5,192)	(2,817)	(12)	(38.3)	
Combined Total (Avg)		(10,217)	18,349	5,812	5,104	-	(4,853)	(1,692)	(16)	(36.8)	

TYPING GUIDE SHEET

TABLE 56. ST177 VESSEL TEMPERATURES AND PRESSURES

Vessel	Pressure, kPag (psig)	Temperature, °C
High Pressure Separator	6,723-7,447 (975-1,080)	-
Low Pressure Separator	552-676 (80-98)	32.0-45.8
Gun Barrel	0 (0)	31.7-41.6
Flotation Unit	0 (0)	31.5-41.2

Pressure Drops Through System

Table 57 traces pressure drops from the producing formations through the system. The table includes only the wells producing water. The pressure drops through the ST177 system were higher than on most other platforms. In particular, high-pressure drops occur at the chokes and through the high-pressure separator control valve. The data are recorded to permit examining the theory that pressure drop and turbulence develop small-drop dispersions which are difficult to remove in separation equipment.

TABLE 57. ST177 PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Formation (SIBHP)	23,080-59,187 (3,447-8,584)		
		perforations, static head, pipes	6,785-39,667 (984-5,753)
Flowing Tubing Pressure	1,724-25,512 (250-3,700)		
		chokes, valves, pipes	3,172-18,341 (460-2,660)
High Pressure Separator	6,723-7,447 (975-1,080)		
		control valve, pipes	1,138-10,101(1) (165-1,465)(1)

(continued)

EPA-287 (Cin.)
(4-76)

TABLE 57. (CONTINUED)

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Low Pressure Separator	552-676 (80-98)	control valve, pipes	552-676 (80-98)
Gun Barrel	0		

(1) Range includes pressure drops from tubing to low-pressure separator.

Chemical Addition

Three chemicals were added by metering pumps as listed in Table 58. Demulsifier and antifoamer usage was monitored by measuring the chemical level in the feed pump reservoirs twice a day. The water treatment chemical usage was monitored by observing the pump down rate in a gauge glass twice a day.

The gun barrel is batch treated with 19 dm^3 of biocide and 19 dm^3 of scale preventative twice per month. The biocide is Tretolite X-CIDE and the scale preventative is Tretolite SP-36. These chemicals were not used during the nine-day program.

Observations and Operator Reports

An effort was made to record any event that could affect effluent water oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures, and the survey team made their own observations.

All the storage tanks were filled with water as a part of the hurricane shutdown that occurred on July 10, 1979, three days before the Program started. This water was pumped to the gun barrel during the first four days of the survey period. Table 59 lists the quantity of bottoms pumped and the percent oil. The quantity of bottoms is based on a pumping rate of 359 m^3/d. The oil concentrations are based on the daily water cut test.

Table 60 lists the percent of oil in the water dump from the low-pressure separator. The water dump valve on the separator was worn and leaked when it was in a closed position. As a result, the valve could not hold an oil/water interface and oil leaked out the water dump. The valve was replaced with a new valve on Day 6. The replacement and adjustment was completed by 1700. The Day 6, 1000 sample was taken during valve maintenanace when there was no flow to the gun barrel.

TABLE 58. ST177 CHEMICAL ADDITION

Chemical	Flow diagram identifier	Addition point	Addition rate	
			dm^3/d	ppmv
Tretolite RP 2256 (Demulsifier)	7B	Between wells and LP Separator	7.6	9.0(1)
Tretolite D-91, "VEZ" (Antifoamer)	20B	Between wells and LP Separator	2.0	2.3(1)
Tretolite FR-81	10	Flotation Unit Influent	22.3	26(1)

(1) Based on average flow of water discharged from flotation unit.

TYPING GUIDE SHEET

TABLE 59. TANK BOTTOMS

Day of program	Hours of pumping	Quantity m^3/d	Oil, percent
01	20	299	-
02	24	359	0
03	24	359	97
04	14	209	99.6
05	0	0	52
06	0	0	3
07	0	0	-
08	3	45	-
09	1	15	-
Mean	-	143	-

Well production interruptions longer than half a day are shown in Table 55. Well 8B which produces 1,036 bpd of water was shut in Days 4 and 5. This reduced the produced water flow by 20 percent. The lowest flotation unit temperatures occurred on these days.

TABLE 60. ST177 LOW PRESSURE SEPARATOR WATER DUMP

Day	Time	Oil, percent
01	08	0.3
01	13	55.0
02	08	56.0
02	13	0.5
03	08	0.3
03	13	61.0
04	08	0.3
04	13	17.0
05	08	0.4
05	13	80.0
06	08	65.5
06	13	58.0
07	08	0.5
07	13	0.6
08	08	0.3
08	13	0.4
09	08	0.2
09	13	0.5
Mean		22.0

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

Numerous washings occurred as shown in Table 61. The detergent usually used was GS1011, Heavy Duty Degreaser, from Great Southern Valve and Chemical. A solvent called Varsol from Exxon was used for turbine washings. Tide laundry detergent was used one day. The washdown on Day 4 at 1300 was a large one which used 625 dm^3 of GS1011. Washdowns and rainwater flowed to sumps and was then pumped to the gun barrel.

TABLE 61. ST177 WASHDOWNS

Day	Washdown period	Detergent
03	0600-0700	Tide
04	0900	GS1011
	1030	GS1011
	1300	GS1011
06	1500	GS1011
	0800-0900	Varsol & GS1011
07	0430-0700	Varsol & GS1011
	0700	GS1011
	1715	GS1011
08	1200-1300	GS1011

Three rainstorms occurred during the program. The day and time of these rains are shown in Table 62.

TABLE 62. ST177 RAIN

Day	Time
06	1230-1430
07	1500-1600
08	1415-1440

The rain on Day 8 was very heavy and occurred shortly before the 1500 sample period. Most of the flow was to the sump. The pumped flow from the sump was estimated to add 330 m^3/d to the flow rate to the gun barrel. The rain on the other two days did not occur at times that would influence the regular effluent samples.

The flotation unit froth flow was calculated twice per day. The flow varied from 0 to 134 m^3/d for short periods with an average of 70 m^3/d.

EPA-287 (Cin.)
(4-76)

DATA PRESENTATION AND EVALUATION

Comprehensive data tables are presented throughout this section.

Effluent Oil Content

The survey of ST177 was conducted immediately following a hurricane. The production operations were generally upset for the first six days and relatively stable for the last three. The conditions and activities that could affect brine quality or quality were described in the subsection on Observations and Operator Reports. They included pumping water from tank bottoms, low-pressure separator level control valve failures, detergent washdowns, and flow increases caused by rainfall. It was not uncommon during the first six days for three of these events to occur at the same time. This made it difficult to identify a specific reason for the higher effluent oil content values.

Table 63 presents a listing of all oil content test results. Figure 33 is a time-indexed plot of GR-Oil in and out of the flotation unit. Figure 34 is a similar plot for IR-Oil.

The graphs illustrate high variability of the flotation influent for all nine days and of the flotation effluent for the first six. The effluent oil content was relatively uniform for the last three days. The effluent oil content peaks generally correspond with influent peaks but do not match them exactly. The exceptionally high effluent oil content values all occurred during the six-day upset period following the hurricane.

The ranges of test results are as follows:

Flotation Effluent GR-Oil - 4 to 373 mg/l,
Flotation Effluent IR-Oil - 28 to 542 mg/l,
Flotation Influent GR-Oil - 147 to 2,336 mg/l,
Flotation Influent IR-Oil - 49 to 1,990 mg/l.

Flotation unit effluent oil content histograms are presented in Figure 35 and Figure 36. Figure 37 is a regression plot of GR-Oil versus IR-Oil. Paired GR-Oil and IR-Oil samples were taken about one minute apart from a flowing stream. The differences in paired test results include sampling and testing variations.

Table 64 presents a summary comparison of test results by the two methods.

The effluent oil content test results for ST177 have higher standard deviations than most other platforms in the survey. The ranges in test results are wide. The histograms illustrate that the data are not normally distributed. All of this can be attributed to the general upset of operations following the hurricane.

The IR-Oil averaged higher than the GR-Oil. The regression plot in Figure 37 indicates that there is significant correlation for results by the two oil content procedures.

TABLE 63. ST177 MAJOR BRINE TESTS

Sample time		LP separator effluent (5A20)	Flotation unit influent (9--i)		Flotation unit effluent (9--0)							
		IR-Oil	GR-Oil	IR-Oil	GR-Oil	IR-Oil	IR-Oil w/silica gel Dispersed	IR-Oil w/silica gel Soluble	Filtered brine IR-Oil	Surface tension	Flow rate Out(2)	Flow rate Skimmings
Day	Hour	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	3,132	194	237	53	67	68	0	44	60	1,064	47
01	10	-	-	288	48	89	-	-	-	-	1,064	47
01	13	55(1)	254	317	59	85	76	9	-	-	1,064	47
01	15	-	-	144	66	79	-	-	-	-	1,064	47
02	08	56(1)	174	258	74	83	68	15	46	74	1,152	47
02	10	-	-	330	50	82	-	-	-	-	1,152	47
02	13	5,080	237	347	78	106	55	51	-	-	1,152	41
02	15	-	-	182	58	89	-	-	-	-	1,152	41
03	08	2,751	447	428	221	334	313	21	79	62	807	41
03	10	-	-	271	134	195	-	-	-	-	807	41
03	13	61(1)	184	288	107	135	127	8	-	-	807	41
03	15	-	-	216	198	271	-	-	-	-	807	41
04	08	2,709	147	237	373	542	508	34	131	50	637	41
04	10	-	-	385	81	152	-	-	-	-	637	41
04	13	17(1)	266	508	68	114	76	38	-	-	637	128
04	15	-	-	322	33	61	-	-	-	-	637	128
05	08	4,233	2,336	1,609	17	37	17	20	56	74	629	128
05	10	-	-	322	141	63	-	-	-	-	629	128
05	13	80(1)	301	440	25	51	30	21	-	-	629	134
05	15	-	-	288	20	39	-	-	-	-	629	134
06	08	66(1)	1,664	1,990	74	78	59	19	452	55	842	30
06	10	-	-	49	26	47	-	-	-	-	-	-
06	13	58(1)	1,010	1,185	28	169	129	40	-	-	842	71
06	15	-	-	711	102	47	-	-	-	-	842	71
07	08	4,910	336	516	41	63	49	14	50	76	813	74
07	10	-	-	432	14	34	-	-	-	-	813	74
07	13	5,842	198	309	21	36	20	16	-	-	813	74
07	15	-	-	292	9	30	-	-	-	-	813	74
08	08	3,386	175	758	9	33	17	16	42	78	866	68
08	10	-	-	381	12	30	-	-	-	-	866	68
08	13	3,979	305	322	12	28	12	16	-	-	866	68
08	15	-	-	169	9	30	-	-	-	-	866	68
09	08	2,201	399	212	10	30	14	16	47	78	828	90
09	10	-	-	229	16	31	-	-	-	-	828	90
09	13	4,656	187	330	4	28	10	18	-	-	828	90
09	15	-	-	237	9	29	-	-	-	-	828	90
10	08	-	-	-	-	-	-	-	-	-	-	-
10	10	-	-	-	-	-	-	-	-	-	-	-
10	13	-	-	-	-	-	-	-	-	-	-	-
10	15	-	-	-	-	-	-	-	-	-	-	-
Minimum		2,201	147	49	4	28	10	0	42	50	629	30
Maximum		5,842	2,336	1,990	373	542	508	51	452	78	1,152	134

(1) Oil content reported in percent as measured by the water cut test.
(2) Based on well test data.

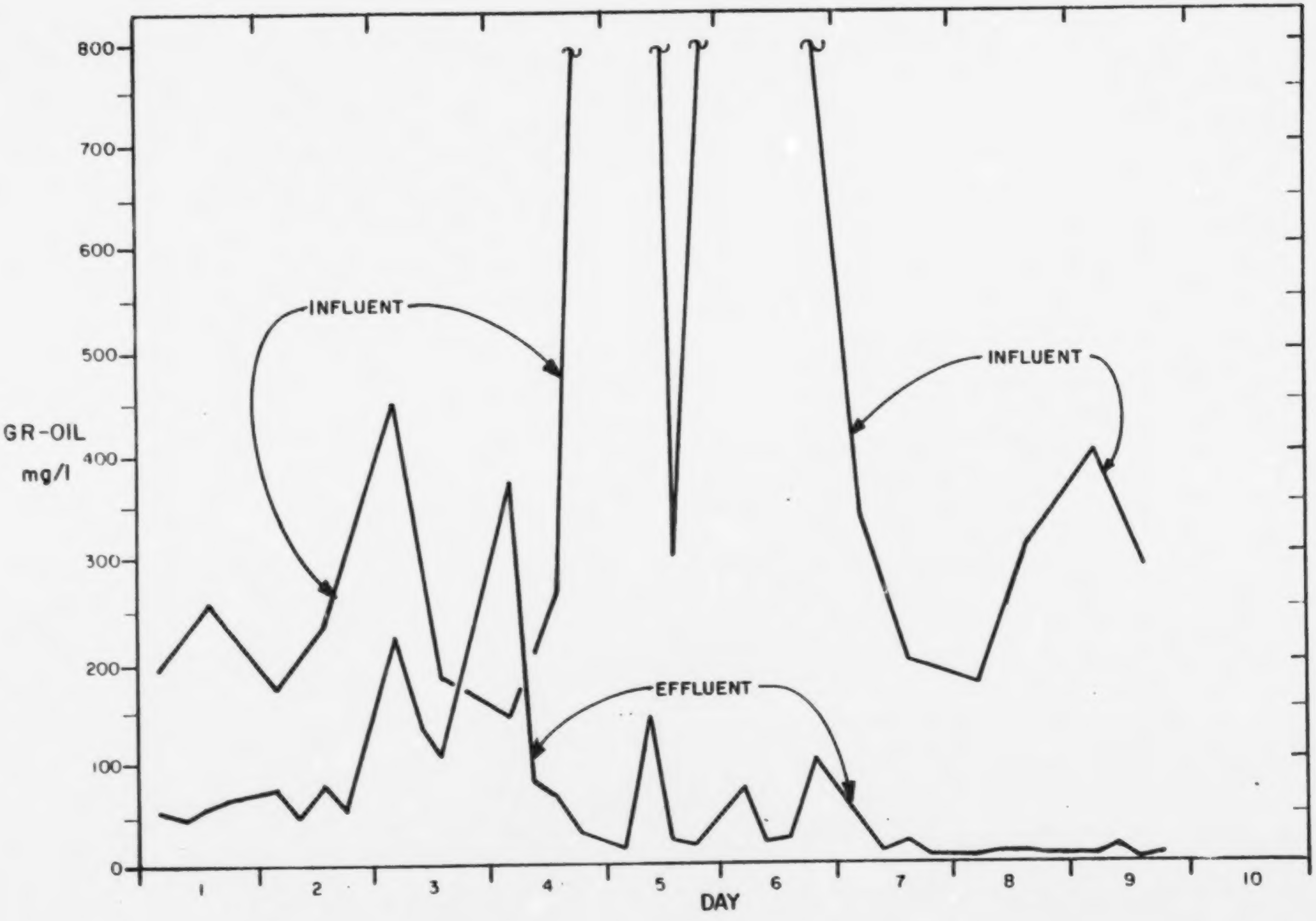


Figure 33. ST177 flotation unit performance, GR-oil vs time.

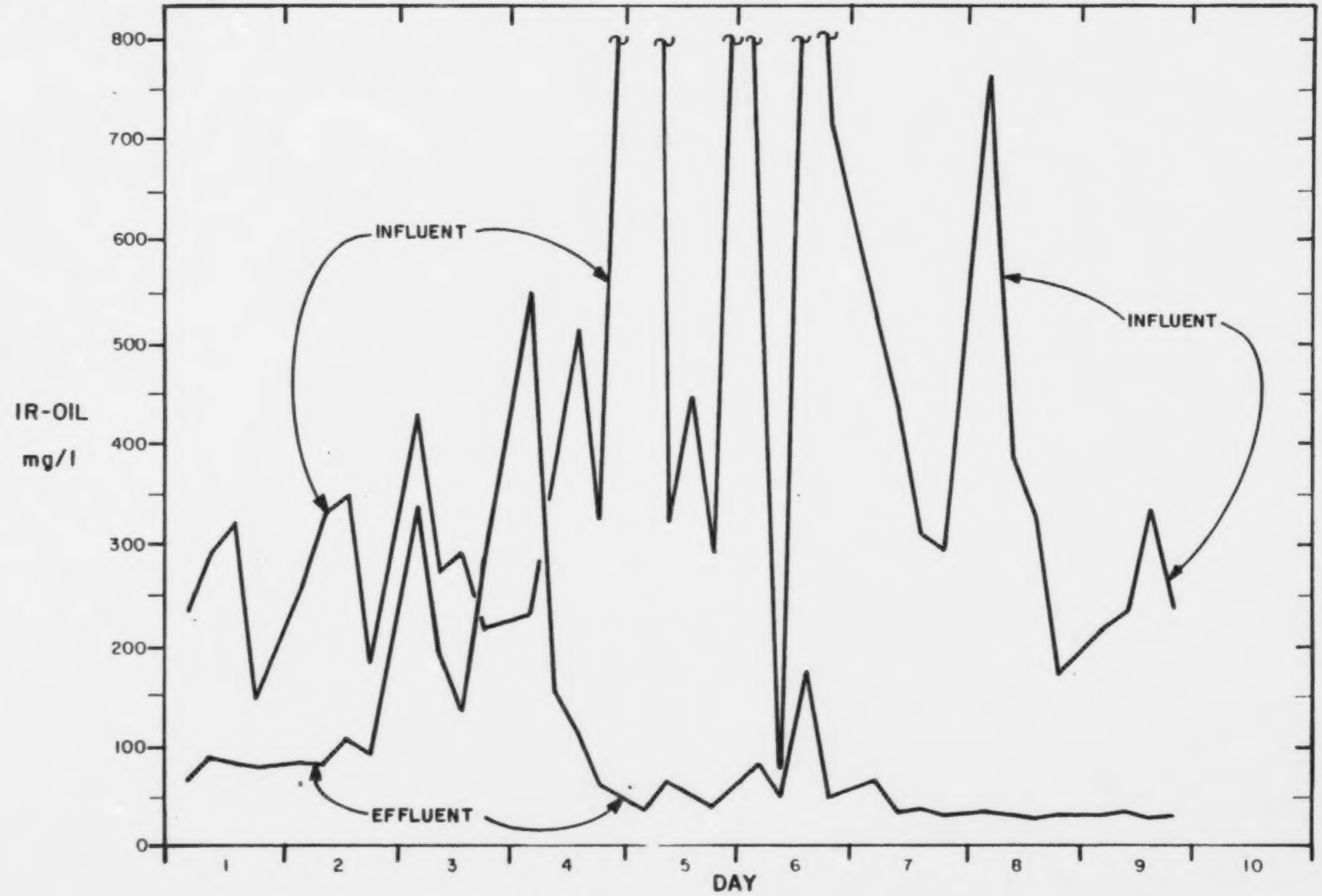


Figure 34. ST177 flotation unit performance, IR-oil vs time.

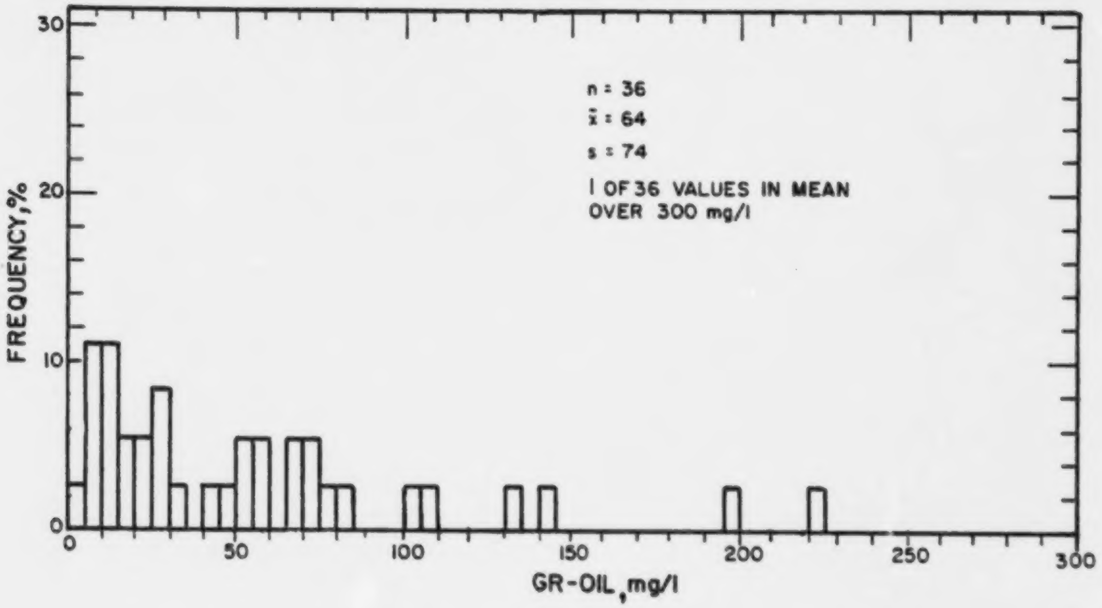


Figure 35. ST177 flotation unit effluent, GR-oil histogram.

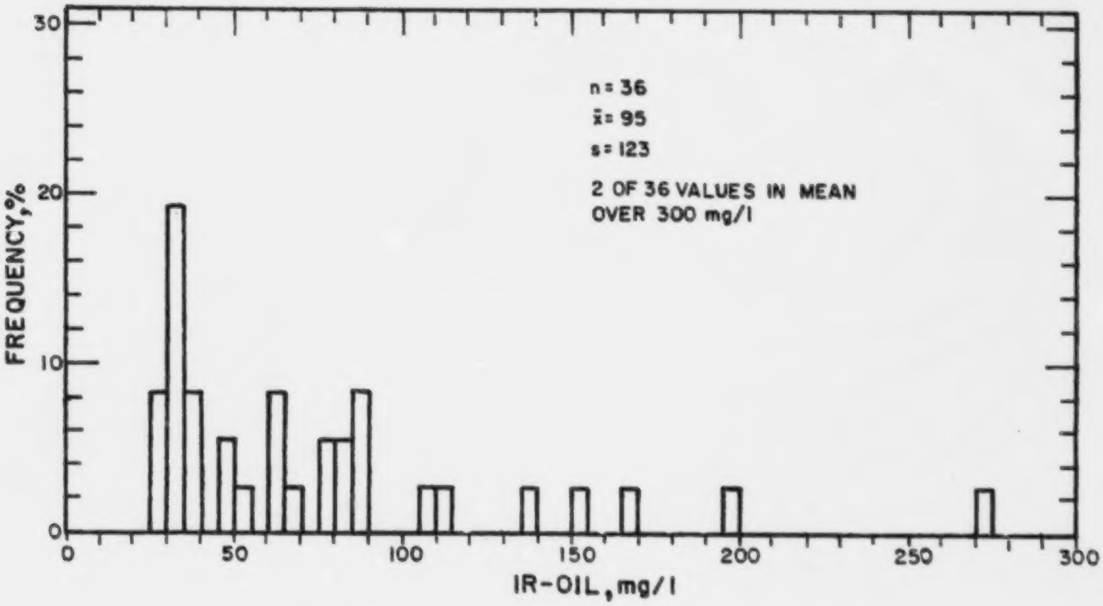


Figure 36. ST177 flotation unit effluent, IR-oil histogram.

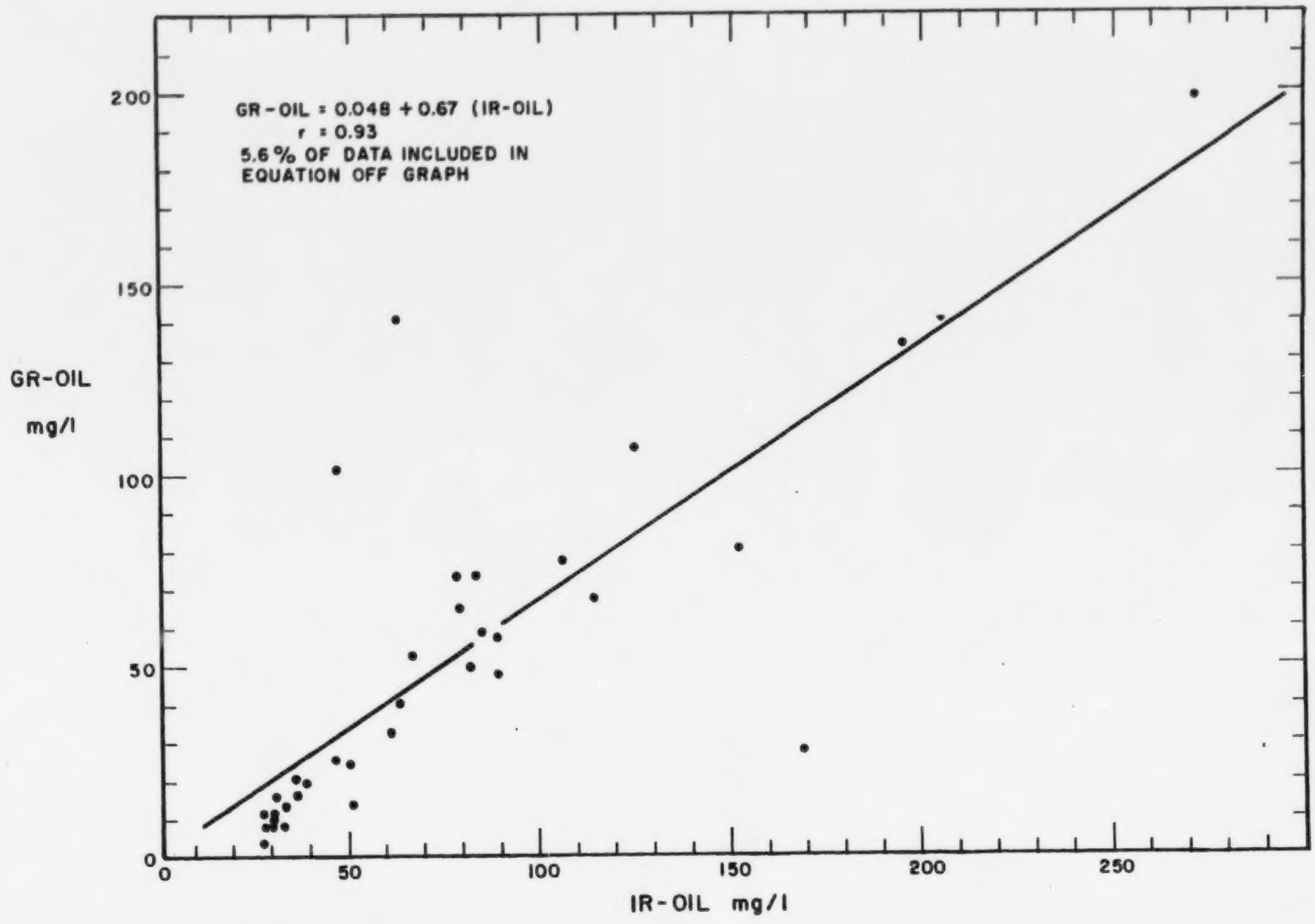


Figure 37. ST177 flotation unit effluent, infrared-gravimetric regression.

TABLE 64. ST177 FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	36	36
Mean, ($\bar{x}$), mg/l	64	95
Minimum, mg/l	4	28
Maximum, mg/l	373	542
Standard Deviation,(s),mg/l	74	103
	Paired tests	
Number, (n)	36	
Mean of Differences, ($\bar{\Delta}$), mg/l	38	
Standard Deviation, (s_{Δ}), mg/l	37	

All oil content tests for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 63. A summary of these tests is presented in Table 65.

TABLE 65. ST177 SOLUBLE OIL SUMMARY

	Flotation effluent		
Analysis or test	Range mg/l	Mean mg/l	Proportion of total, percent
IR-Oil(1)	28-542	113	100
Dispersed Oil	10-508	92	81
Soluble Oil	0-51	21	19

(1) Includes only 18 test results when IR-Oil w/Silica Gel tests were obtained on same sample.

On average, 19 percent of the oil in the effluent was soluble oil and 81 percent was dispersed.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 38. Extrapolation of the regression lines to zero dispersed oil indicate a residual IR-Oil of 18 mg/l and a residual GR-Oil of 6 mg/l after all dispersed oil has been removed.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

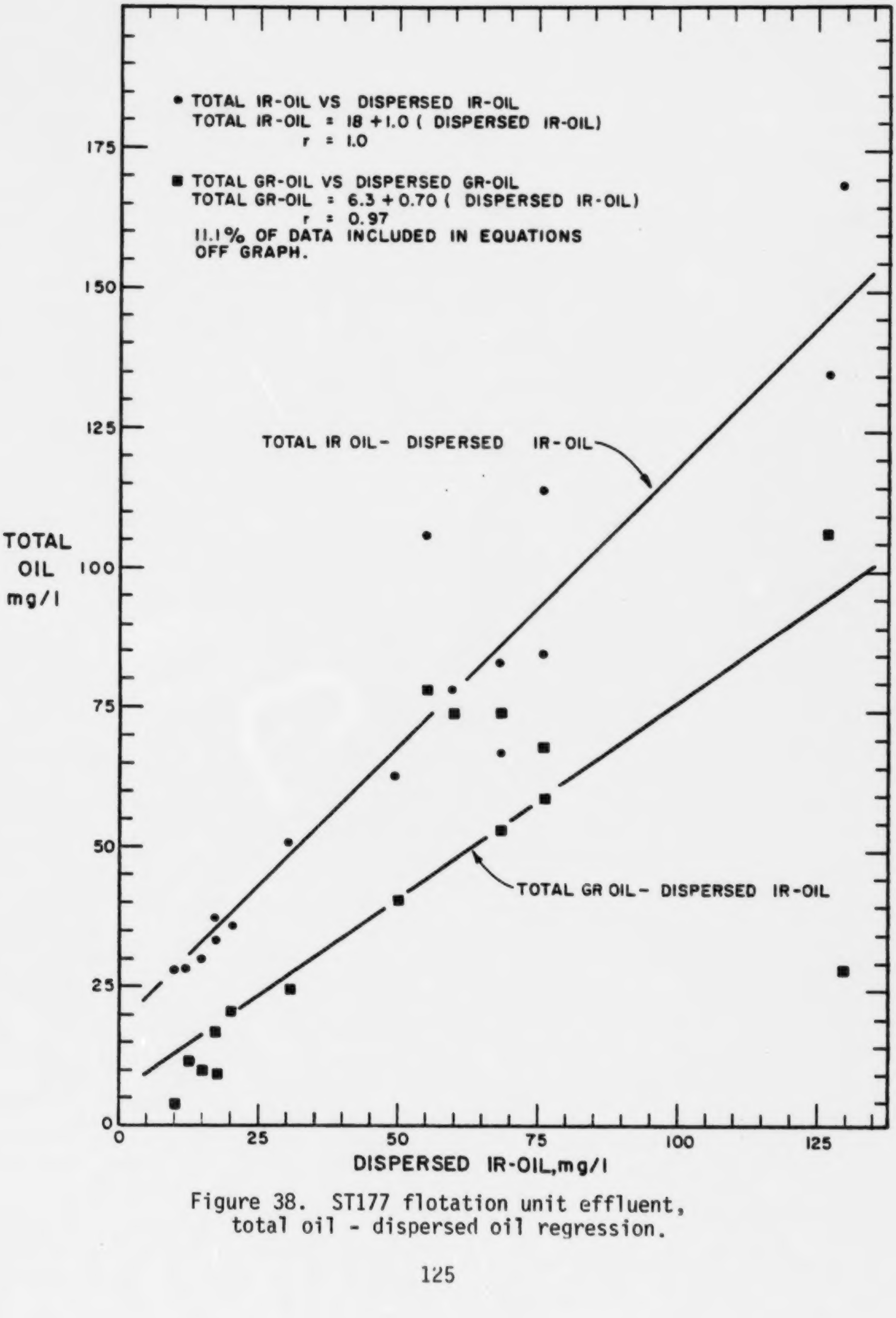


Figure 38. ST177 flotation unit effluent, total oil - dispersed oil regression.

Surface Tension

All surface tension test results are reported in Table 63. The mean surface tension of the flotation effluent was 67 dynes/cm with minimum and maximum values of 50 and 78 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 924-11.6\ (\text{Surface Tension})$$
$$r = 0.70$$

A decrease in IR-Oil is indicated when surface tension increases.

Suspended Solids

Suspended solids test results are listed in Table 66 for major sampling points. A suspended solids summary for ST177 is presented in Table 67.

More than half of the solids are Freon soluble. All solids decrease across the flotation unit.

Figure 39 presents time-indexed plots of Freon insoluble suspended solids in the flotation influent and effluent, and of flotation effluent dispersed oil. The suspended solids samples were taken at 1500 each day and the dispersed oil samples were taken at 0800 and 1300 each day.

The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when flotation influent or effluent suspended solids are higher. The lack of a readily apparent relationship may be because the samples were not all taken at the same time and also because of the substantial variability of the suspended solids test.

Filtered Brine

The filtered brine IR-Oil content of ST177 effluent was in the range of 42 to 452 mg/l. Four of nine filtered brine test values were higher than the corresponding unfiltered IR-Oil test values. The other five were lower. Conclusions cannot be drawn from the filtered brine test results because of the inconsistent pattern of the data.

Flotation Unit Performance

Figure 40 is a regression plot of IR-Oil in and out of the flotation unit. The plotted data and the regression equation indicate that effluent oil content is essentially independent of influent oil content. The slope of the regression line is -0.015 and the correlation coefficient is -0.059.

Figure 41 is a regression plot of flotation effluent IR-Oil and percent hydraulic loading. The plotted data appear to indicate essentially no correlation between oil content and hydraulic loading. The calculated regression relationship indicates oil content decreases as hydraulic loading increases with minor correlation. This intuitively false indication may be because many upsets occurred, short term flow variations were not measured, and the

EPA-287 (Cin.)
(4-76)

TABLE 66. ST177 SUSPENDED SOLIDS TESTS

Sample time		Low pressure separator, out (5A20)					Flotation unit, in (9--1)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	15	141	102	39	2	37	114	94	21	6	15	211	188	23	5	18
02	15	114	90	24	5	20	126	94	32	12	20	78	60	18	11	7
03	15	75	59	16	3	14	102	78	24	12	13	77	59	18	12	6
04	15	87	68	19	10	9	81	63	18	4	14	23	17	6	3	3
05	15	117	96	21	6	15	117	99	18	3	15	27	20	7	4	3
06	15	82	51	32	3	29	104	85	19	5	14	18	13	6	5	1
07	15	125	76	50	8	42	840	760	80	24	57	25	18	7	1	6
08	15	85	57	28	11	17	304	291	13	6	7	18	13	5	2	3
09	15	54	46	8	6	2	118	96	22	4	18	18	12	6	2	4
10	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Minimum		54	46	9	2	2	81	63	13	3	7	18	12	5	1	1
Maximum		141	102	50	11	42	840	760	80	24	57	211	188	23	12	18

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTION HERE

TABLE 67. ST177 SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 5A20	9--i	9--0
Total	98	212	55
Freon Soluble	72	184	44
Freon Insoluble	26	27	11
Acid Soluble	6	8	5
Fixed	21	19	6

Note: Some numbers do not check because of rounding.

calculated flows were in the narrow range of 26 to 47 percent of the flotation unit design capacity.

Gun Barrel Performance

Thirty-six IR-Oil tests and eighteen GR-Oil tests were run on the gun barrel effluent. There was a common sampling point for the gun barrel effluent and the flotation unit influent. The test results for this sample point (9--i) are listed in Table 63.

The IR-Oil content of the gun barrel effluent was in the range of 49 to 1,990 mg/l with a mean of 432 mg/l. The sample on which the IR-Oil content of the 49 mg/l was determined was taken at a time when there was no flow to the gun barrel. Excluding this value, the lowest IR-Oil was 144 mg/l. The lines labeled "influent" in Figure 33 and Figure 34 illustrate sample-to-sample variations in oil content.

The results of two susceptibility to separation tests on the gun barrel effluent are reported in Table 68. The mean IR-Oil content after five minutes of static settling for the two tests was 210 mg/l. For comparison, the IR-Oil content of the gun barrel effluent was in the range of 169 to 758 mg/l for the two days when the settling tests were run.

The largest oil drop detected by the particle size test in the gun barrel effluent had a diameter of 55 μm.

Miscellaneous Brine Tests

All other brine test results for ST177 are listed in Tables 69, 70, 71, and 72. The results for the following tests were in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variations in effluent oil content on ST177. These parameters will be discussed with respect to variations between platforms in Section 17.

BEGIN LAST LINE OF TEXT
TTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

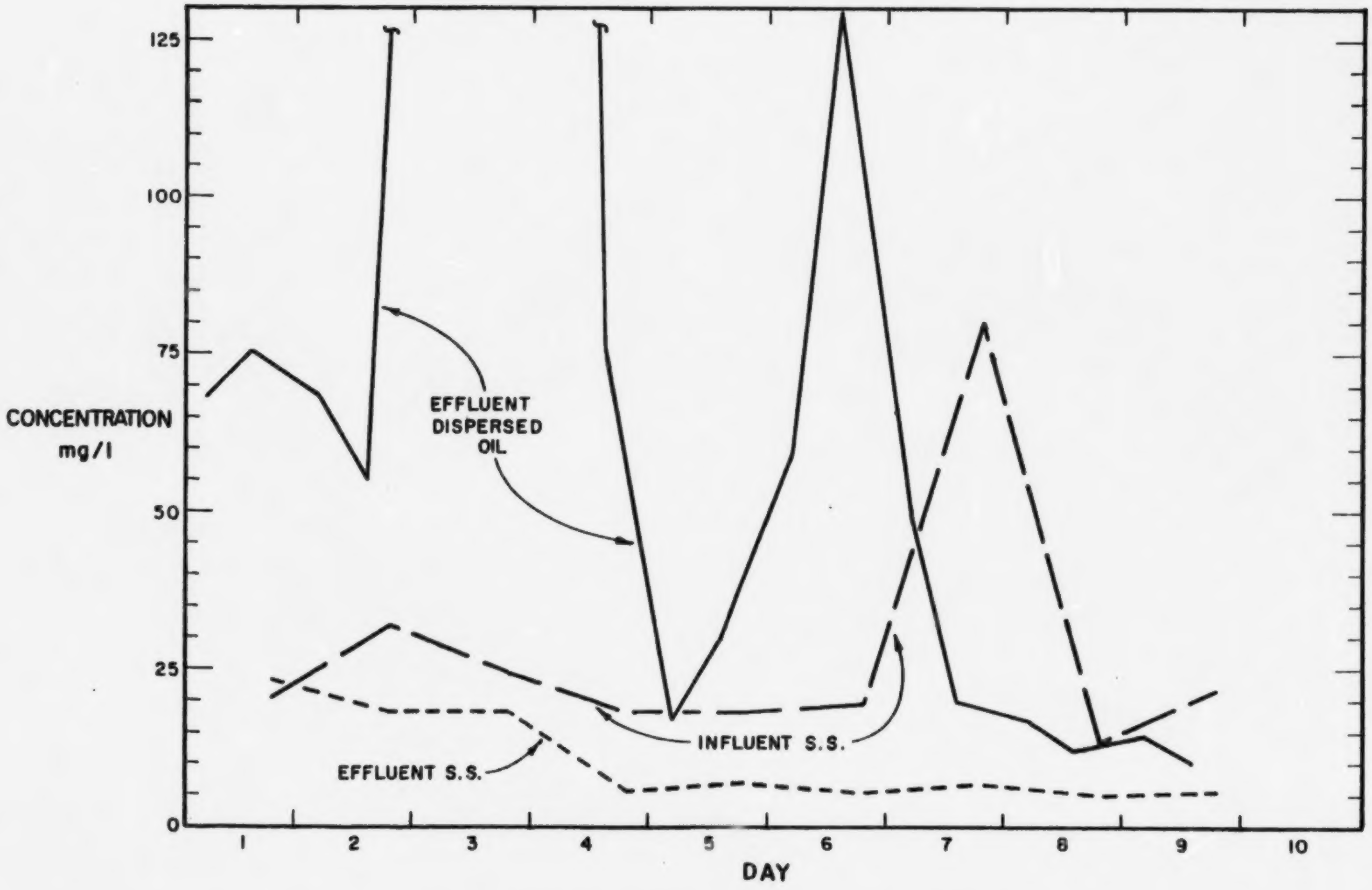


Figure 39. ST177 flotation unit Freon insoluble suspended solids.

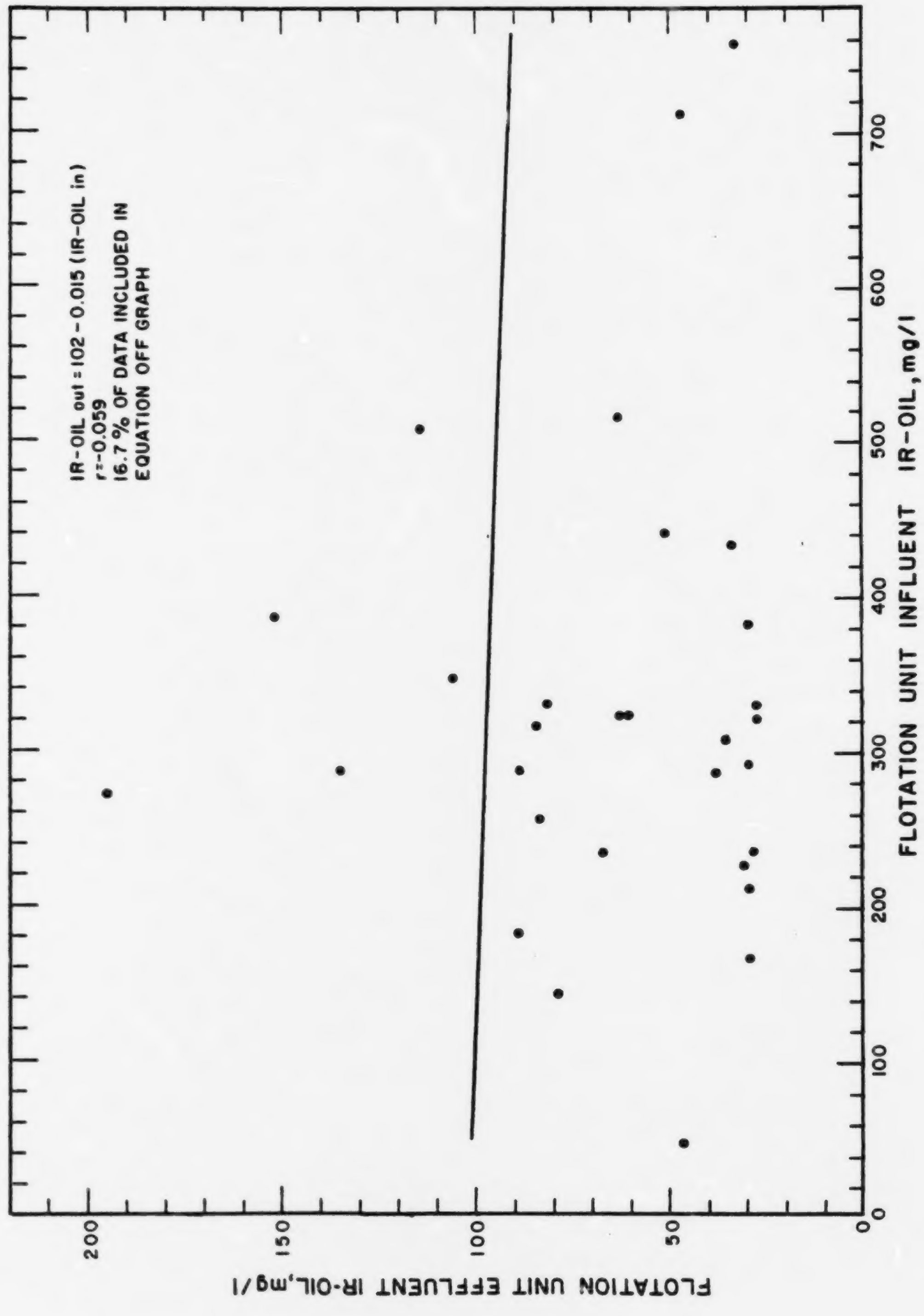


Figure 40. ST177 flotation unit in-out IR-oil regression.

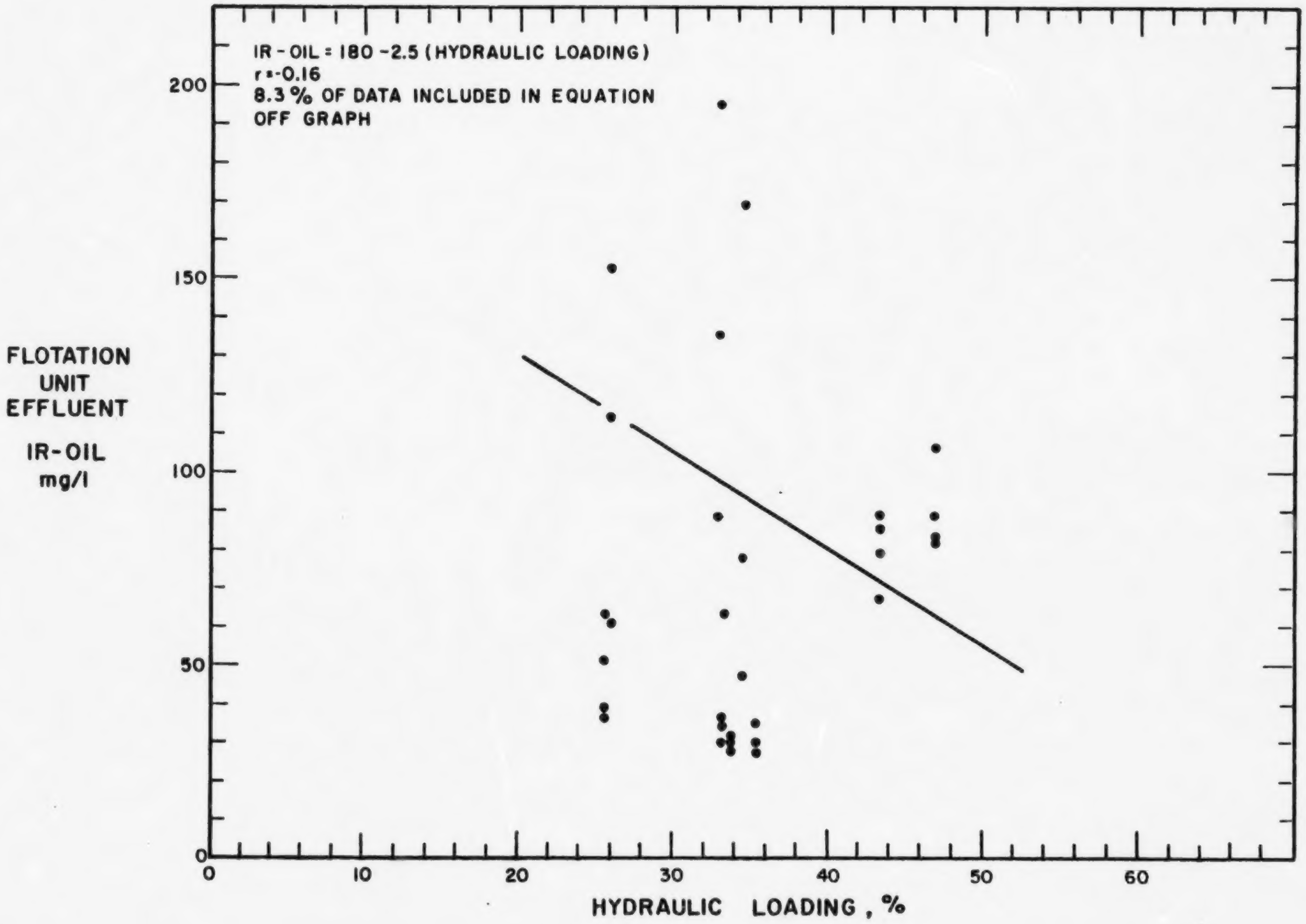


Figure 41. ST177 flotation unit, hydraulic loading - infrared oil regression.

BEGIN FIRST LINE OF
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 68. ST177 GUN BARREL EFFLUENT SUSCEPTIBILITY TO SEPARATION

Sampling time	Test number 1	Test number 2	Mean
Day	7	8	-
Hour	9	9	-
Minute	30	30	-

Settling time, minutes	IR-Oil, mg/l 1	IR-Oil, mg/l 2	IR-Oil, mg/l Mean
0-1 (1)	495	186	340
5	271	148	210
15	178	110	144
30	131	84	108
60	114	85	100
120	114	85	100

(1) The actual settling time is the time required to handle the separatory funnel after filling and to draw a sample, and is estimated at not more than one minute.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on ST177. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil test results are listed in Table 73 and Table 74. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number and are of primary significance for comparisons between platforms. Two equilibration tests were run.

The limited number of tests run on crude oil provided only a limited characterization of the crude oil.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 69.ST177 SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °F					pH	Specific gravity (1)
Day	Hour	14--0	5A20	9F-0	9--i	9--0	9--0	9--0
01	08	-	-	-	-	38.8	-	1.168
01	10	30.4	45.2	40.3	40.9	40.7	6.4	-
02	08	-	-	-	-	39.4	-	1.163
02	10	29.8	45.8	40.5	41.6	41.2	6.4	-
03	08	-	-	-	-	38.8	-	1.163
03	10	33.0	35.0	40.8	41.1	40.5	6.2	-
04	08	-	-	-	-	32.4	-	1.135
04	10	32.0	34.3	32.4	32.5	32.6	6.2	-
05	08	-	-	-	-	31.5	-	1.129
05	10	29.4	32.1	31.5	31.7	31.6	6.4	-
06	08	-	-	-	-	34.8	-	1.152
06	10	29.0	32.0	35.0	35.4	35.2	6.4	-
07	08	-	-	-	-	35.0	-	1.158
07	10	27.5	38.0	36.5	36.2	36.5	6.2	-
08	08	-	-	-	-	34.8	-	1.148
08	10	29.0	36.0	36.0	35.7	35.6	6.4	-
09	08	-	-	-	-	35.7	-	1.145
09	10	29.0	35.3	35.0	34.5	35.2	6.4	-
10	08	-	-	-	-	-	-	-
10	10	-	-	-	-	-	-	-
Mean		30.0	37.1	36.4	36.6	36.1	6.3	1.151
Minimum		27.5	32.0	31.5	31.7	31.5	6.2	1.129
Maximum		33.0	45.8	40.8	41.6	41.2	6.4	1.168

Note: Sample point identification numbers as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 70. ST177 SULFATE REDUCING BACTERIA

Sample point	Bacteria per milliliter Sample No. 1	Bacteria per milliliter Sample No. 2
Flotation Unit - Out (9--0)	0	0
Flotation Unit - In (9--i)	0	0
LP Separator - Out (5A20)	0	0
Sump - Out (14--0)	10,000	1,000

Sample Day and Hour: 09 at 15

TABLE 71. ST177 WATER CUT AT VARIOUS SAMPLE POINTS

Sample time Day	Sample time Hour	Water cut, % Flotation unit froth	Water cut, % Oil storage bottoms	Water cut, % Sump out
01	10	100	-	91
02	10	100	100	77
03	10	98	3	86
04	10	-	0	86
05	10	100	48	6
06	10	97	97	80
07	10	100	-	100
08	10	100	-	100
09	10	100		2
Mean		99	50	70
Minimum		97	0	2
Maximum		100	100	100

TABLE 72. ST177 IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	97,000
Calcium (Ca)	1,500
Magnesium (Mg)	310
Barium (Ba)	750
Chloride (Cl)	111,000
Sulfate (SO_4)	245
Alkalinity (as HCO_3)	584
Iron (Total)	26
Sulfide (as H_2S)	0.94
Total Dissolved Solids	
Summation	211,000
Gravimetric	203,000

Sample Day and Hour: 09 at 15

TYPING GUIDE SHEET
CENTER
BEGIN FIRST LINE OF TEXT HERE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTION HERE
9-1/8
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA-287 (Cin.)
(4-76)

TABLE 73. ST177 CRUDE OIL MISCELLANEOUS TESTS (1)

Sample time Day	Sample time Hour	Temperature °C	Specific gravity (2)	Surface tension dynes/cm (2)
01	08	33.4	0.846	30
02	08	31.0	0.848	30
03	08	31.7	0.846	29
04	08	31.5	0.830	30
05	08	32.6	0.838	29
06	08	35.0	0.834	29
07	08	33.8	0.838	30
08	08	32.1	0.840	29
09	08	35.4	0.857	30
Mean		32.9	0.842	30
Minimum		31.0	0.830	29
Maximum		35.4	0.857	31

Sample time Day	Sample time Hour	Viscosity at 37.77°C Kinematic centistokes	Viscosity at 37.77°C Absolute centipoise
09	15	4.05	3.47

Equilibration at 82°C
Brine TDS = 100,000 mg/l

	Test No. 1	Test No. 2
Oil/Water Ratio	4/1	4/1
IR-Oil, mg/l	31	17

---

(1) Samples taken from LACT unit.
(2) Reported for approximately the temperature in table.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 74. ST177 CRUDE OIL BOILING RANGE DISTRIBUTION

	Run No. 1	Run No. 2	Mean
Initial Boiling Point,°C	150	150	150
Final Boiling Point,°C	490	470	480
Boiling range, °C	Percent recovered		
Below - 200	43.1	42.4	42.8
200 - 250	10.6	10.4	10.5
250 - 300	19.4	19.2	19.3
300 - 350	13.4	12.5	13.0
350 - 400	6.8	6.4	6.6
400 - 450	5.5	8.3	6.9
450 - 500	0.8	0.8	0.8
500 - 550	0.4	0.1	0.2
Total	100.0	100.1	100.1

Sample Day and Hour: 09 at 15

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

SECTION 9

PLATFORM BM2C

GENERAL

The ten-day testing survey was conducted on Platform BM2C from March 4, 1980 through March 13, 1980.

A description of the production facilities, the test program, and data presentation and evaluation are presented in this section.

Four survey team members arrived at the platform on March 3 and the test equipment was set up the same day. Oil company personnel unloaded the equipment and provided living quarters, work space, sample taps, a flow monitor and the utilities needed to conduct the program.

Transfer of equipment to the platform was delayed for two days by high waves. After testing started on March 4, the weather did not interrupt the sampling schedule. The minor operational problems that occurred also did not interrupt the schedule.

FACILITIES AND OPERATIONS

Production From Wells

The number of wells flowing to the production system varied from day to day.

Four gas-lift wells were produced only a few hours on the first day and then again on the ninth and tenth days. One of the compressors supplying the lift gas was out of service for repairs during the non-productive period.

Twenty-three wells were produced continuously for the ten-day survey period. Two other wells were produced intermittently on the fifth, sixth, and seventh days.

The estimated daily production of the twenty-three wells that were produced continuously was 1,901 m^3/d (11,957 bpd) of crude oil, 720 m^3/d (4,526 bpd) of water and 370,530 std m^3/d (13,085 Mcfd) of gas based on well test data. The calculated water cut was 27 percent.

Twenty-five percent of the oil was gas lifted, and 58 percent of the water was gas lifted.

Production Process System

The flow of oil and water through the system is shown in Figure 42. Design and operating data on major vessels are presented in Table 75. The primary oil/water flow is to a low-pressure three-phase separator. The flow from one well producing primarily gas and water went first to a high-pressure gas/liquids separator before the liquids flowed to the low-pressure separator.

The oil stream from the low-pressure separator passes through an electrostatic oil treater for additional brine separation. The crude oil is then pumped to a pipeline for sale.

A demulsifying agent, Tretolite RP-34, is added to the low-pressure manifold ahead of the low-pressure separator at the rate of 15 dm^3/d (4 gpd).

Figure 43 is a flow schematic for the water handling system. The primary produced water flow is from the low-pressure separator to the corrugated plate interceptor (CPI), to the flotation unit, and then to discharge.

Skimmings from the CPI and the flotation unit flow to a large wet-oil tank. Miscellaneous drains discharge to skim sumps, and any oil recovered is pumped to the wet-oil tank. Oil and water that accumulate in the wet-oil tank are pumped to the oil treater. The water settling in the oil treater flows to the inlet of the CPI.

The flow was monitored continuously with an orifice plate meter on the CPI inlet. The skimmings flow from the CPI and the flotation unit were estimated based on the time to fill a measured volume in the wet-oil tank. The effluent flow was calculated by subtracting the skimming flows from the CPI inlet flow.

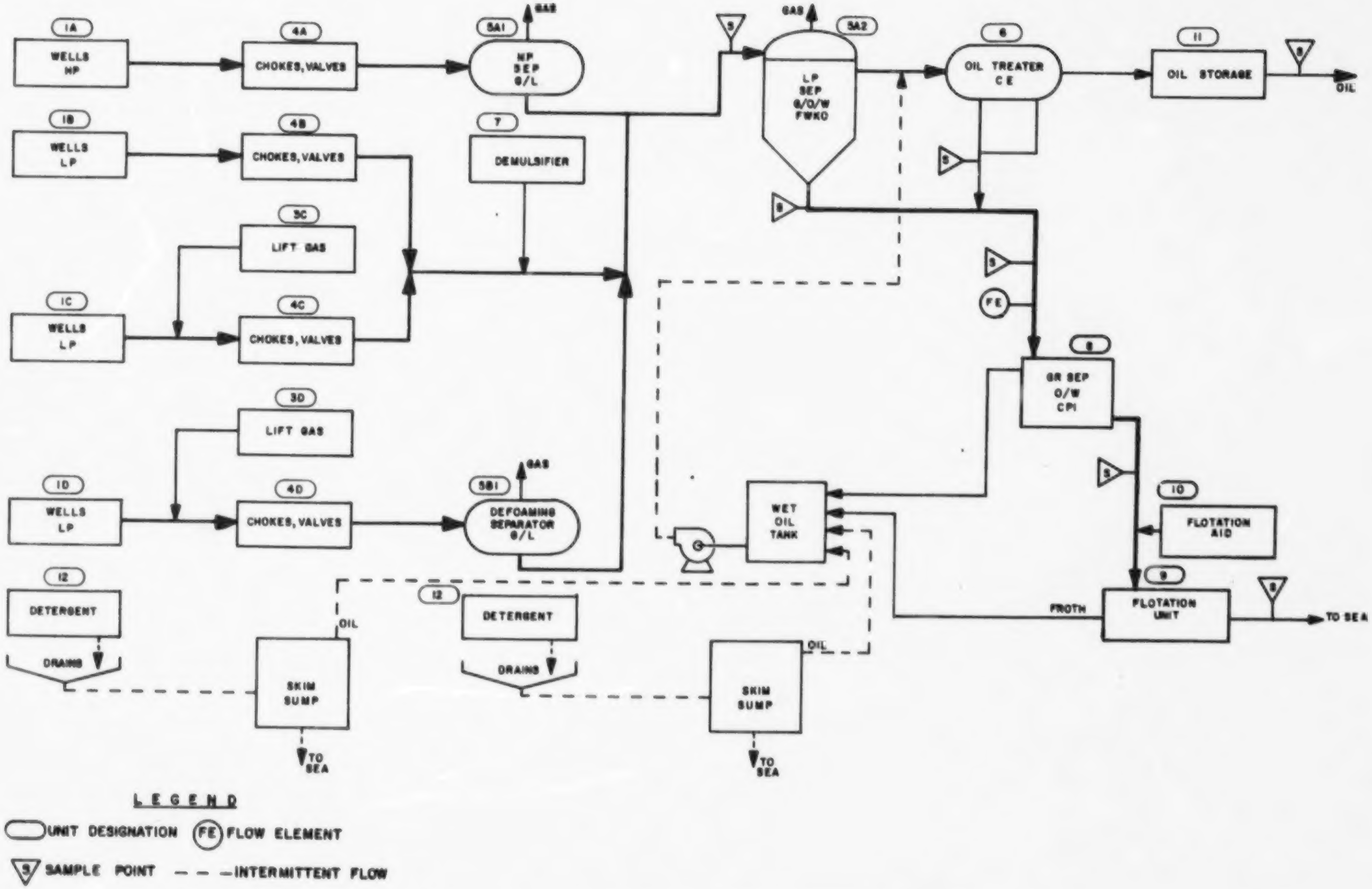
The average flow rates reported in Figure 43 are based on averaging thirty-four measured and calculated values corresponding with sampling times. The flows are higher than those estimated from well test data. The differences could be because the flows at the sampling times were higher than 24-hour average flows, or the differences could be attributed to inaccuracy of flow estimates based either on monitoring or on well test data.

A water treating chemical, Tretolite FR-87, is added to the flotation unit inlet at the approximate rate of 17 dm^3/d (4.5 gpd).

The CPI unit is a gravity separator of proprietary design supplied by Monarch Separators, Inc. Oil separates as the water flows between parallel plates spaced approximately 2 cm (0.75 in.) apart. Figure 44 is an undimensioned representational sketch of a CPI unit.

The CPI unit on BM2C is a 2-pack unit. The approximate dimensions of each pack are 1 m high, 1 m wide, and 1.75 m long. Based on the manufacturer's recommended sizing procedure and the conditions prevailing on BM2C during the survey, the CPI on BM2C should accomplish separation of 30-µm oil drops at a flow rate of 981 m^3/d (6,170 bpd), or separation of 40-µm oil drops at flow rates up to 1,908 m^3/d (12,000 bpd). Average hydraulic

EPA-287 (Cin.)
(4-76)



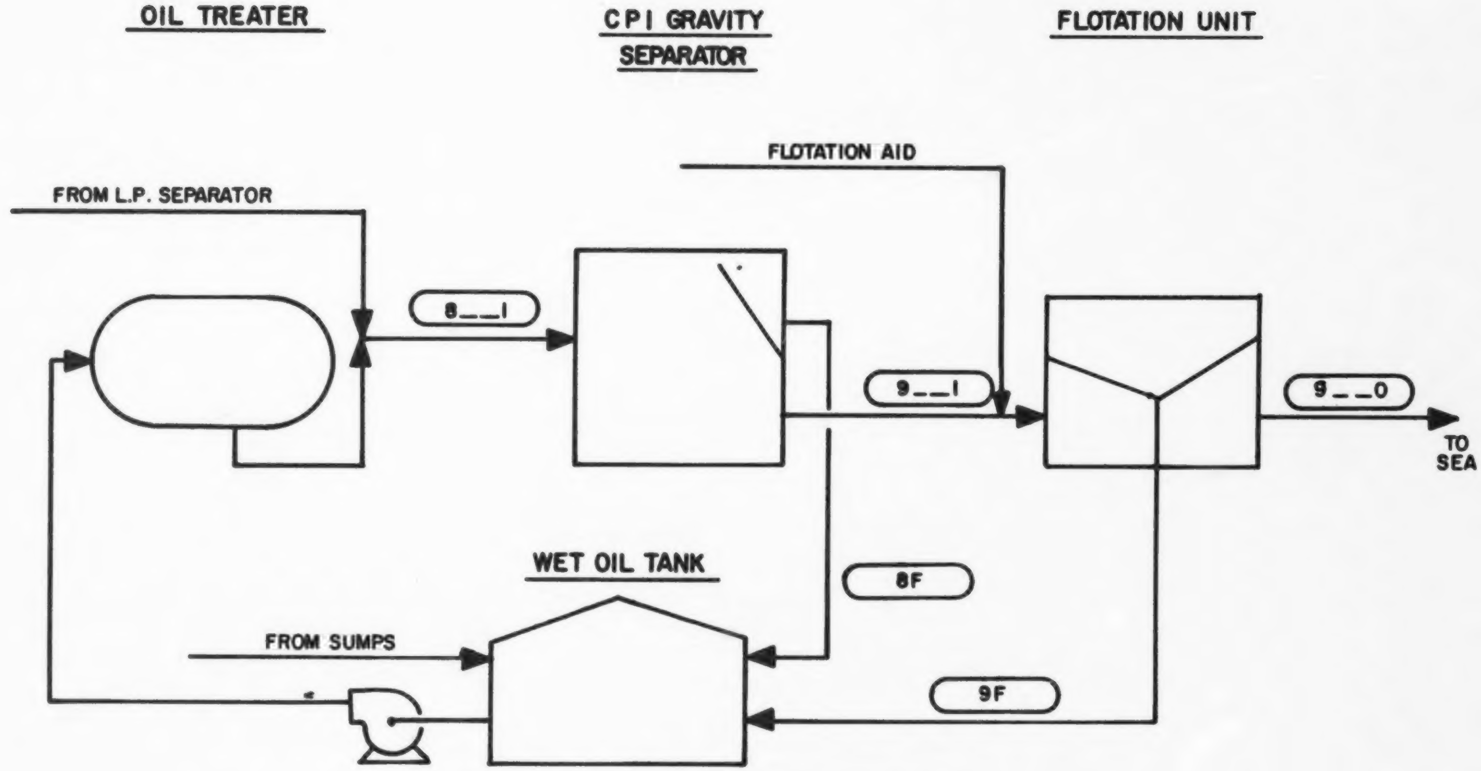
1A
WELLS HP
1B
WELLS LP
1C
WELLS LP
1D
WELLS LP
3C
LIFT GAS
3D
LIFT GAS
4A
CHOKES, VALVES
4B
CHOKES, VALVES
4C
CHOKES, VALVES
4D
CHOKES, VALVES
5A1
HP SEP G/L
GAS
7
DEMULSIFIER
5B1
DEFOAMING SEPARATOR G/L
GAS
5A2
LP SEP G/O/W FWKO
GAS
6
OIL TREATER CE
11
OIL STORAGE
OIL
FE
8
GR SEP O/W CPI
10
FLOTATION AID
9
FLOTATION UNIT
FROTH
TO SEA
WET OIL TANK
12
DETERGENT
DRAINS
OIL
SKIM SUMP
TO SEA
12
DETERGENT
DRAINS
OIL
SKIM SUMP
TO SEA
LEGEND
UNIT DESIGNATION
FE FLOW ELEMENT
SAMPLE POINT
INTERMITTENT FLOW

Figure 42. Flow diagram, production process system, BM2C.

TABLE 75. BM2C VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 9-1				
	5A1 High pressure gas/liquid separator	5A2 Low pressure 3-phase separator	6 Oil treater, chem electric	8 Gravity separator, CPI	9 Flotation unit, mechanical, dispersed gas
Trade Name or Vessel Type	Horizontal Cylinder	Vertical Cylinder Cone-Bottom	Horizontal Cylinder	Monarch(1)	Wemco Model 76
Design Parameters					
Dimensions, m, (ft)					
Diameter, O.D.	-	4.88(16)	4.27(14)	-	-
Length, S.S.	-	-	10.67(35)	-	-
Length	-	-	9.14(30)	-	7.9(26)
Width	-	-	-	-	1.98(6.5)
Height	-	-	-	-	-
Separation Surface Area, m^2, (ft^2)					
Total	-	18.7(201)	-	-	15.7(169)
Per Cell	-	-	-	-	3.9(42)
Separation Volume, m^3, (bbl)					
Total	-	-	-	-	11(71)
Water Phase	-	29.3(184)	-	-	-
Number of Cells	-	-	-	-	4
Flow Rate, m^3/day, (bpd)(2)	-	-	-	1,908(12,000)(3)	4,090(25,725)
Overflow Rate Per Cell,(m^3/d)/m^2,(bpd/ft^2) (4)	-	-	-	-	1,049(612)
Recycle Rate, Percent of Flow	-	-	-	-	-
Retention Time, min	-	-	-	-	4
Average Operating Parameters					
Temperature, $^oC(^oF)$	-	46(115)	-	46(115)	45(113)
Pressure, kPag (psig)	12,710(1,844)	531(77)	462(67)	0(0)	0(0)
Flow Rate, m^3/d(bpd) (2)	-	995(6,257)	242(1,521)	1,160(7,294)	995(6,257)
Flow Rate, Percent of Design (2)	-	-	-	-	24
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)(2)	-	53(31)	-	-	255(149)
Recycle Rate, Percent of Flow	-	-	-	-	-
Froth Flow, Percent of Flow	-	-	-	-	17

(1) Proprietary unit with two plate packs.
(2) Based on effluent flow.
(3) Based on removing 40 um oil drops.
(4) Overflow rate is surface area divided by flow rate.


OIL TREATER
CPI GRAVITY SEPARATOR
FLOTATION UNIT
FLOTATION AID
FROM L.P. SEPARATOR
8__I
9__I
9__O
TO SEA
WET OIL TANK
8F
FROM SUMPS
9F

WATER FLOW		8F	8__I	9F	9__I	9__O
	m^3/d	77	1237	165	1160	995
	bpd	484	7778	1037	7294	6257

Figure 43. BM2C water handling system flow schematic.

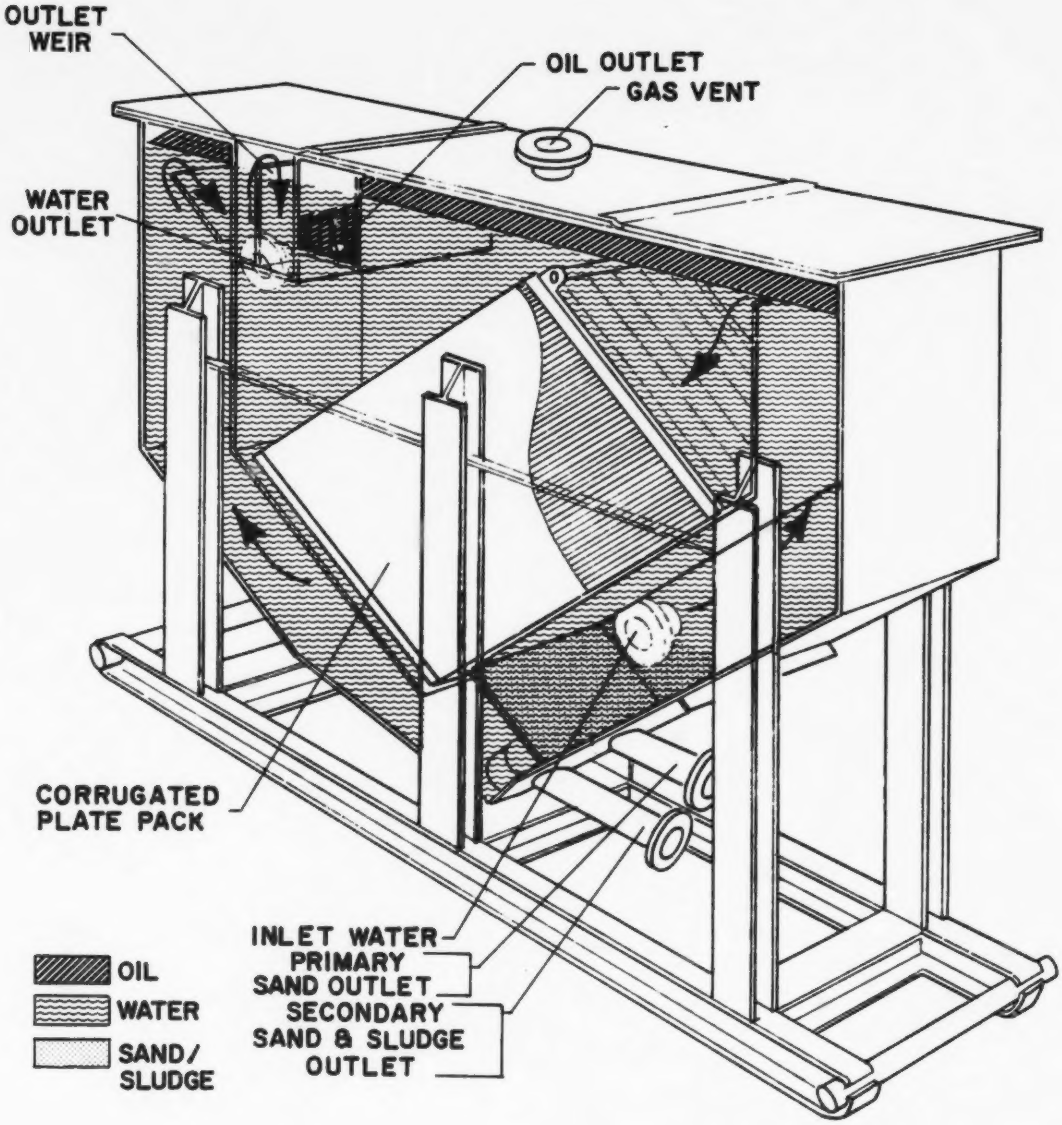

OUTLET WEIR
OIL OUTLET
GAS VENT
WATER OUTLET
CORRUGATED PLATE PACK
INLET WATER
PRIMARY SAND OUTLET
SECONDARY SAND & SLUDGE OUTLET
OIL
WATER
SAND/ SLUDGE

Figure 44. BM2C corrugated plate interceptor sketch.

TYPING GUIDE SHEET

loading was estimated to be 1,160 m^3/d (7,294 bpd), or 580 m^3/d per plate pack.

The flotation unit (Wemco 1 + 1, Model 76) on BM2C is a proprietary four-cell unit with mechanical gas eduction. This type of unit was described in Section 6 and is depicted in Figure 6.

The unit is designed to handle 4,090 m^3/d (25,725 bpd) of water. The average loading was 995 m^3/d or 24 percent of design.

SITE SPECIFIC TEST PROGRAM

The planned test program for brine samples is presented in Table 76. The number of samples to be taken in ten days and the time the samples are to be taken each day are listed. The listed program was carried out with only minor variations as noted below.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations and records of operations are reported in this subsection.

Flow Monitoring

The flow rate was monitored continuously at the CPI inlet as described in the subsection on the process system. Using this measured flow rate and the estimating procedures previously described, a flow rate was estimated and recorded each time a sample was taken at the following points: CPI inlet, outlet, and skimmings; flotation unit inlet, outlet, and skimmings. The data for the flotation unit are listed in Table 77.

Because of orifice plate changes, the flow monitor was not fully operational until the middle of the second day.

The water flow patterns were presented in Figure 42 and Figure 43. The primary continuous flow was produced water from the wells. The primary recycle flow was the water returned to the oil treater from the wet-oil tank. When the wet-oil tank recycle pump came on, the flow at the CPI inlet increased by about 709 m^3/d (4,460 bpd). The recycle pump would be off for several hours and then on for several hours. The on/off durations did not follow a set pattern.

Well Test Data

The well test data provided by the operator are presented in Table 78. Data on wells from remotely located Platform E are not included. Two Platform E wells flowed to BM2C intermittently on Days 5, 6, and 7. The two E wells were known high-water producers estimated at rates over 159 m^3/d

EPA-287 (Cin.)
(4-76)

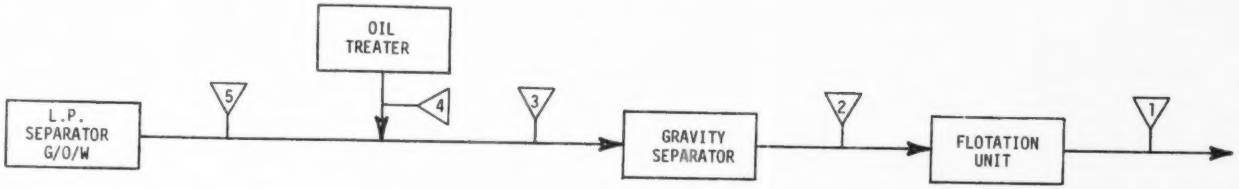


TABLE 76. BM2C TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS									
	1		2		3		4		5	
	9--0		9--i		8--i		6--0		5A20	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests										
Infrared Oil	40	8,10,13,15	40	8,10,13,15	20	8,13	2	8	2	8
Temperature	10	8	10	8	10	8	2	8	2	8
pH	10	8	-	-	-	-	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-	-	-	-	-
Water Surface Tension(2)	10	8	-	-	10	8	-	-	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	10	8	-	-	-	-
IR-Oil Filtered Brine	20	8,13	-	-	10	8	-	-	-	-
Susceptibility to Separation(3)	-	-	-	-	3	13	-	-	-	-
Laboratory Tests										
Gravimetric Oil	40	8,10,13,15	10	8	-	-	-	-	-	-
Suspended Solids	10	8	10	8	10	8	-	-	-	-
Ionic Analysis	1	(1)	-	-	-	-	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.									
Particle Size Distribution(4)	3	13	3	13	3	13	-	-	-	-

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/silica gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/silica gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

TABLE 77. BM2C MAJOR BRINE TESTS

Sample time		Gravity separator influent (8--i)					Flotation unit influent (9--i)	Flotation unit effluent (9--0)								
Day	Hour	IR-Oil mg/l	IR-Oil w/silica gel "Dispersed" mg/l	IR-Oil w/silica gel "Soluble" mg/l	Filtered brine IR-Oil mg/l	Surface tension dynes/cm	GR-Oil mg/l	IR-Oil mg/l	GR-Oil mg/l	IR-Oil mg/l	IR-Oil w/silica gel Dispersed mg/l	IR-Oil w/silica gel Soluble mg/l	Filtered brine IR-Oil mg/l	Surface tension dynes/cm	Flow rate Out m^3/d	Flow rate Skimmings m^3/d
01	08	555	420	135	63	57	-	-	275(B)	37	1	36	54	70	-	-
01	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
01	13	840	-	-	-	-	-	75	22	39	13	26	45	-	-	-
01	15	-	-	-	-	-	-	84	28	40	-	-	-	-	-	-
02	08	609	504	105	71	49	74	118	21	35	5	30	71	60	-	-
02	10	-	-	-	-	-	-	97	26	50	-	-	-	-	-	-
02	13	529	-	-	-	50	-	92	24	42	5	37	53	-	1,139	327
02	15	-	-	-	-	-	-	88	97(B)	40	-	-	-	-	834	109
03	08	824	681	143	55	53	110	168	27	48	17	31	22	60	1,139	327
03	10	-	-	-	-	-	-	164	18	39	-	-	-	-	834	109
03	13	525	-	-	-	60	-	261	22	40	2	38	55	-	834	109
03	15	-	-	-	-	-	-	189	17	38	-	-	-	-	834	109
04	08	340	256	84	59	54	129	240	16	37	4	33	52	58	834	109
04	10	-	-	-	-	-	-	80	17	34	-	-	-	-	1,139	327
04	13	197	-	-	-	49	-	101	179(B)	39	2	37	56	-	774	109
04	15	-	-	-	-	-	-	105	12	33	-	-	-	-	774	109
05	08	357	101	256	55	51	135	202	17	40	0	40	0(A)	57	834	109
05	10	-	-	-	-	-	-	75	17	35	-	-	-	-	1,172	327
05	13	185	-	-	-	45	-	84	22	39	1	38	44	-	1,172	327
05	15	-	-	-	-	-	-	109	15	34	-	-	-	-	741	109
06	08	311	193	118	56	48	57	84	20	39	1	38	46	59	1,199	327
06	10	-	-	-	-	-	-	92	17	35	-	-	-	-	1,199	327
06	13	248	-	-	-	51	-	101	20	37	3	34	51	-	899	109
06	15	-	-	-	-	-	-	168	26	33	-	-	-	-	899	109
07	08	563	471	92	59	52	114	134	19	50	8	42	55	45	774	109
07	10	-	-	-	-	-	-	252	20	41	-	-	-	-	774	109
07	13	538	-	-	-	42	-	252	21	40	3	37	54	-	774	109
07	15	-	-	-	-	-	-	126	15	38	-	-	-	-	1,172	327
08	08	420	231	189	227	55	138	219	26	45	17	28	57	64	752	33
08	10	-	-	-	-	-	-	210	18	8(A)	-	-	-	-	719	33
08	13	487	-	-	-	56	-	219	29	42	2	40	59	-	752	33
08	15	-	-	-	-	-	-	219	24	40	-	-	-	-	752	33
09	08	580	471	109	261	51	174	252	23	42	5	37	51	62	1,161	55
09	10	-	-	-	-	-	-	210	20	44	-	-	-	-	1,161	55
09	13	454	-	-	-	50	-	130	22	42	8	34	55	-	1,580	327
09	15	-	-	-	-	-	-	130	25	39	-	-	-	-	1,580	327
10	08	563	462	101	277	55	106	143	26	38	0	38	45	60	1,428	327
10	10	-	-	-	-	-	-	210	52	38	-	-	-	-	1,063	76
10	13	647	-	-	-	59	-	227	18	38	2	36	51	-	1,063	76
10	15	-	-	-	-	-	-	286	126(B)	34	-	-	-	-	1,063	76
Minimum		185	101	84	55	42	57	75	12	33	0	26	22	45	719	33
Maximum		840	681	256	277	60	174	286	52	50	17	42	71	70	1,580	327

(A) Not included in statistical analysis. Appears inconsistent with other IR-Oil, GR-Oil and "soluble" oil tests.
(B) Not included in statistical analysis. Salt crystals were observed after freon was evaporated for the test.

TABLE 78. BM2C WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig		Choke size 1/64 in.	API gravity	Days of production
							SIBHP	FTP			
Flowing to High Pressure Separator											
C-8-	-Q-RA	13,995	1,650	0	792	0	-	4,800	13.0	-	All
Flowing to Low Pressure Separator											
C-1A	D10RD	12,247	240	160	0	0	-	900	13.0	35.0	All
C-2-	P-1RA	13,024	382	567	141	0	-	1,225	16.0	34.0	All
C-3-	-D-RD	12,765	496	880	0	0	-	210	44.0	32.0	All
C-4-	-D-RD	12,988	501	900	0	0	-	330	34.0	34.0	All
C10-	-D-RD	13,125	1,001	1,560	0	0	-	360	44.0	38.0	All
C14-	-NBRA	11,533	332	138	0	0	-	2,200	9.0	38.0	All
C16-	-D-RD	12,825	988	1,578	0	0	-	350	44.0	40.0	All
D-4D	-D-RD	12,476	305	629	0	0	-	385	26.0	38.0	All
D-5D	-D-RD	13,000	170	108	0	0	-	425	12.0	37.8	All
D-6-	-P-RC	12,699	80	98	226	0	-	360	23.0	31.9	All
D12-	D10RB	11,889	235	310	724	0	-	600	24.0	31.0	All
D13-	-	-	40	8	0	0	-	200	22.0	33.0	All
D15-	D12RB	12,630	253	375	0	0	-	-	18.0	34.0	All
D17-	D12RB	12,629	2,456	535	11	0	-	686	36.0	36.0	All
D21-	-D-RD	12,658	286	834	0	0	-	500	26.0	30.0	All
D28D	-	-	307	239	7	0	-	262	26.0	36.0	All
Total (Average)		-	8,072	8,919	1,109	-	-	-	-	(34.9)	
Flowing Total		-	9,722	8,919	1,901	-	-	-	-	-	
Gas Lift to Low Pressure Separator											
C-5-	-P-RD	12,477	379*	199*	465*	585	-	360	30.0	27.3	9,10
C-7-	-D-RD	13,056	635	1,011	543	620	-	300	44.0	35.0	All
C-9-	-D-RD	13,335	328	372	372	300	-	250	42.0	37.0	All
C-11	-D-RD	13,003	648	670	446	300	-	300	44.0	37.0	All
C12-	-D-RD	13,658	230	175	676	557	-	230	44.0	35.0	All
C13-	-	-	72	60	540	250	-	215	34.0	31.0	All
C18-	-	-	1,450	750	48	500	-	800	28.0	36.0	All
D-3D	-	-	162*	82*	734*	140	-	350	28.0	27.0	9,10
D-7-	-	-	145*	135*	1,209*	493	-	450	34.0	-	9,10
D11D	D16RB	13,377	74*	46*	182*	275	-	-	44.0	32.0	9,10
Total (Average)		-	3,363	3,038	2,625	-	-	-	-	(33.0)	-
Combined Total (Average)			13,085	11,957	4,526	-	-	-	-	(34.2)	-

*Not included in average or total.

(1,000 bpd) when both wells were flowing.

Pressure Drops Through System

Flowing tubing pressures were obtained from well test records. The pressure of major vessels was recorded twice per day. Pressure drops in the system are reported in Table 79. The data are recorded to permit examining the theory that the turbulence occurring with the pressure drops at chokes and valves may form small particle dispersions that are difficult to remove in the separation equipment.

TABLE 79. BM2C PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
High Pressure Well, Flowing Tubing Pressure	33,072 (4,800)	chokes, valves, pipes	20,350-20,640 (2,951-2,994)
High Pressure Separator	12,450-12,750 (1,806-1,849)	control valves, pipes	11,900-12,240[1] (1,726-1,775)
Low Pressure Wells, Flowing Tubing Pressure	1,380-15,170 (200-2,200)	chokes, valves, pipes	830-14,660 (120-2,126)
Low Pressure Separator	510-550 (74-80)	control valves, pipes	510-550 (74-80)
CPI Separator	0 (0)		

(1) Between high-pressure separator and low-pressure separator.

Chemical Addition

Two chemicals were added continuously by small metering pumps as listed in Table 80.

The rate of chemical addition was measured twice per day and was exceptionally uniform. The maximum rate variation was 2 dm^3/day from the averages in the table for both chemicals.

TABLE 80. BM2C CHEMICAL ADDITION

Chemical	Addition point	Addition rate	
		dm^3/d	ppmv
Tretolite RP-34 (Demulsifier)	Low pressure separator inlet manifold	15	15(1)
Tretolite FR-87 (Flotation aid)	Flotation unit inlet	17	17(2)

(1) Based on average total water flow at the addition point.
(2) Based on average volume of water discharged from the flotation unit.

Observations and Operator Reports

Any occurrences observed by the survey team or reported by the operator were recorded for possible correlation with effluent brine oil content.

Most of the variations from routine continuous operation occurred on the first day. Four gas-lift wells were produced only part of the first day and again the ninth and tenth days. As discussed earlier, one of the compressors supplying the lift gas was down for repair.

From 0700 to 1300 on the first day, the produced brine flowed through two CPI separators in parallel. For the remainder of the survey period the flow was all through one CPI.

A sample tap was not installed on the flotation unit inlet until 1000 on the first day. A short shut in of the flotation unit to install the sample tap prevented taking the 1000 samples.

The flow monitor was not fully operational until the middle of the second day because of various orifice plate changes.

On Days 5, 6, and 7, two wells from another platform flowed intermittently to the BM2C system. The water production from these wells may have been over 159 m^3/d for short periods of time of unknown duration.

Production was stopped completely on Day 7 at 1500 after the 1500 sample was taken. The shutdown was automatic, caused by a high level in the flotation unit. Production was restored in about one-half hour with no apparent effect on the test program.

There was no rainfall drainage during the survey.

Biocides were not used during the survey.

In general, operations were uniform with respect to factors that would be expected to influence effluent oil content.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables for BM2C, summary tables and graphs are interspersed in the text.

Effluent Oil Content

Table 77 presents a listing of oil content test results for the major sampling points. Figure 45 presents a plot of GR-Oil in and out of the flotation unit versus time for the ten-day period. Figure 46 presents the same plot for IR-Oil content. The time-indexed plots are based on four test results per day, except for the plot of flotation unit influent GR-Oil which is based on one test result per day.

The tabulated data and time-indexed plots show that the oil content is relatively consistent from sample to sample. The ranges of test results are as follows:

Flotation Effluent GR-Oil - 12 to 52 mg/l,
Flotation Effluent IR-Oil - 33 to 50 mg/l,
Flotation Influent GR-Oil - 57 to 174 mg/l,
Flotation Influent IR-Oil - 75 to 286 mg/l.

Flotation unit effluent oil content histograms for the two test methods are presented in Figure 47 and Figure 48. Figure 49 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Table 81 presents a summary comparison of test results by the two methods.

The data presented in Table 81 and the histograms indicate that the mean oil content is higher by the IR-Oil test method than by the GR-Oil test method. However, the scatter of the data in the regression plot, Figure 49, indicates significant random differences can be expected in paired tests by the two methods. The standard deviation of 7.0 mg/l for differences in paired tests indicates there is significant variation in the differences.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 77. A summary of these test results is presented in Table 82.

On average, 87.5 percent of the oil in the effluent was soluble oil and 12.5 percent was dispersed oil.

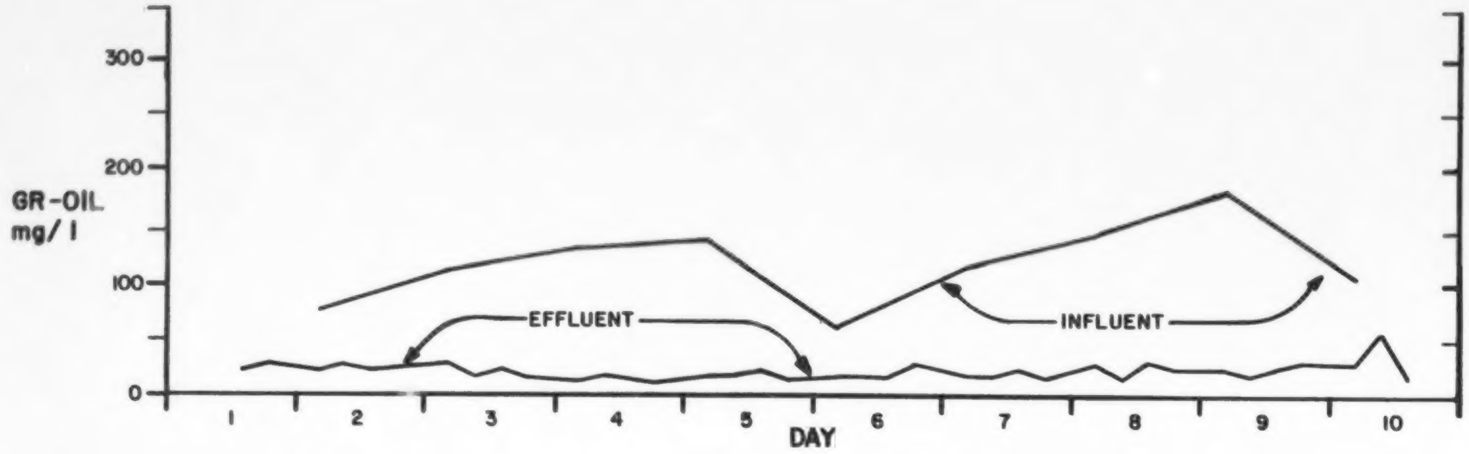


Figure 45. BM2C flotation unit performance, GR-oil vs time.

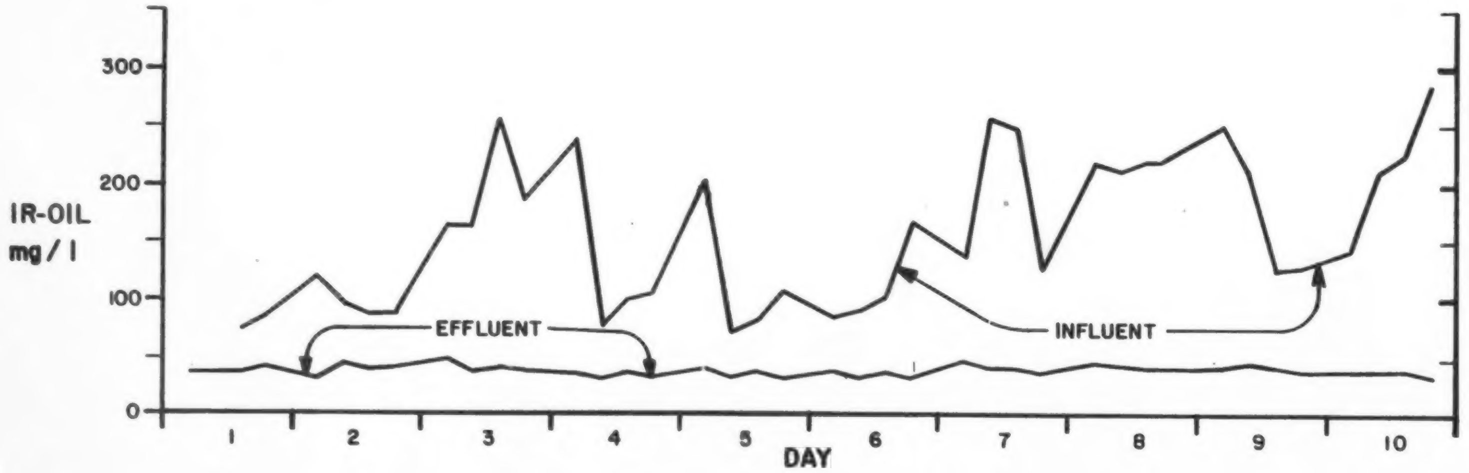


Figure 46. BM2C flotation unit performance, IR-oil vs time.

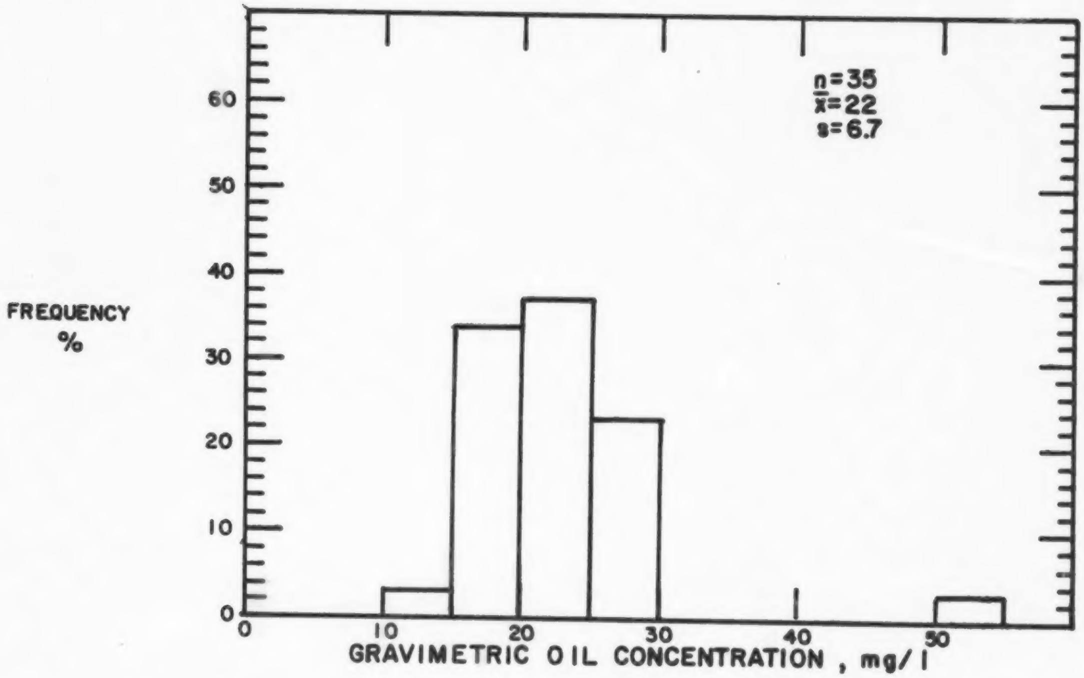


Figure 47. BM2C flotation unit effluent, GR-oil histogram.

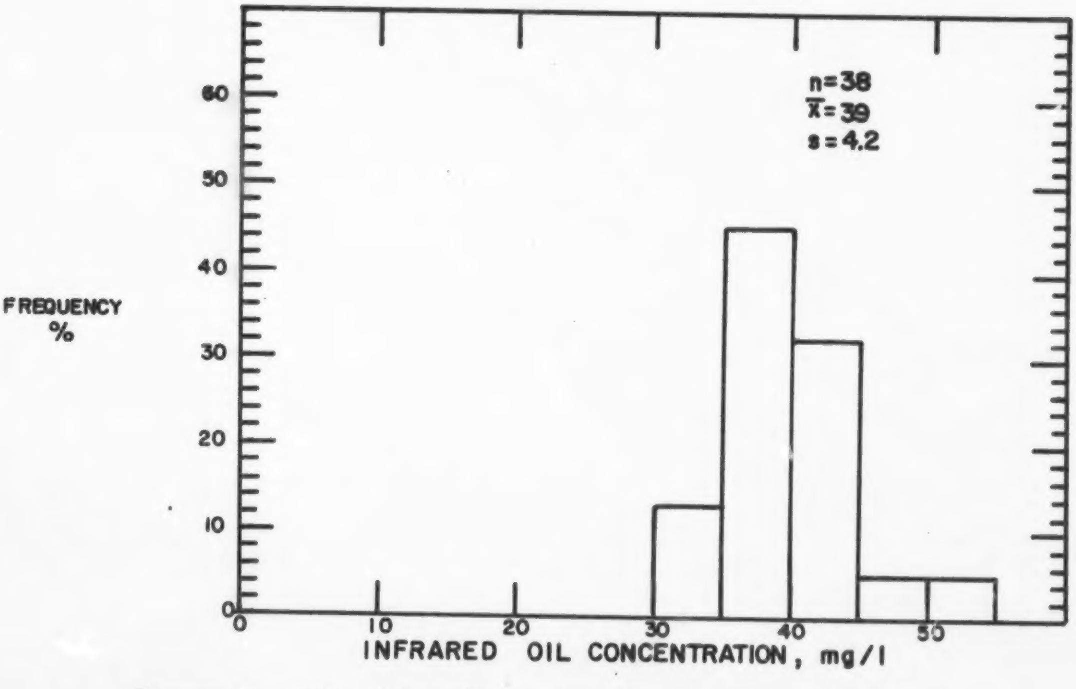


Figure 48. BM2C flotation unit effluent, IR-oil histogram.

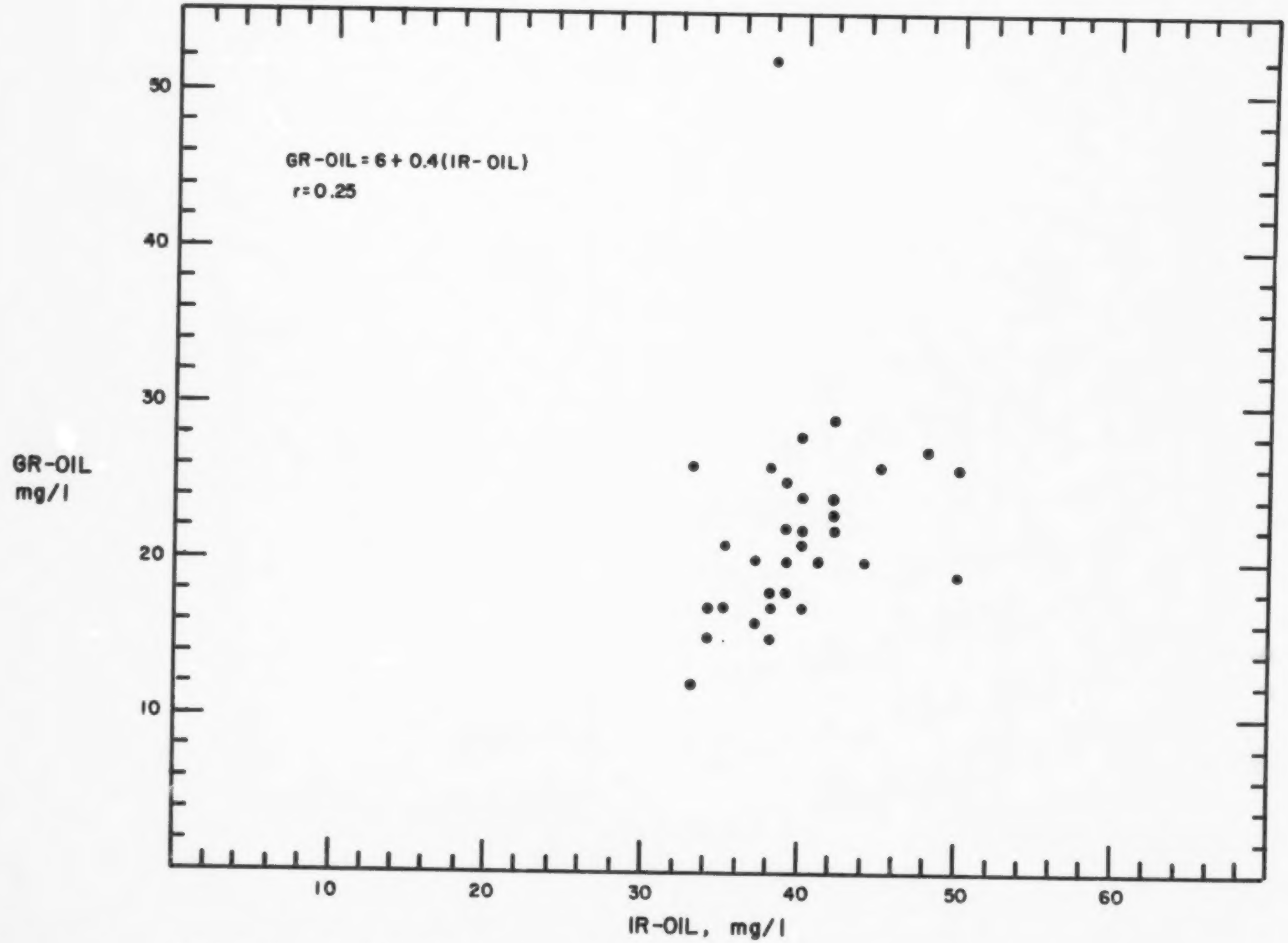


Figure 49. BM2C flotation unit effluent, infrared gravimetric regression.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTION HERE

TABLE 81. BM2C FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	35	38
Mean, $(\bar{x})$, mg/l	22	39
Minimum, mg/l	12	33
Maximum, mg/l	52	50
Standard Deviation,(s), mg/l	6.7	4.2
	Paired tests	
Number, (n)	34	
Mean of Differences, $(\bar{\Delta})$, mg/l	17.6	
Standard Deviation, (s_{Δ}), mg/l	7.0	

TABLE 82. BM2C SOLUBLE OIL SUMMARY

	Flotation effluent		
Analysis or test	Range mg/l	Mean mg/l	Proportion of total, percent
IR-Oil	35-50	40	100
Dispersed Oil	0-17	5	12.5
Soluble Oil	26-42	35	87.5

Note: Table includes only IR-Oil tests when an IR-Oil w/Silica Gel test was run.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 50. Extrapolation of the linear regression lines to zero dispersed oil indicates a residual IR-Oil if 38 mg/l and a residual GR-Oil of 21 mg/l would still be present in the brine after all dispersed oil is removed.

The mean soluble oil content of the gravity separator influent was 133 mg/l, or significantly higher than the mean for the flotation effluent of 35 mg/l.

Surface Tension

All surface tension test results are reported in Table 77. The mean surface tension of the CPI influent is 52 dynes/cm and the mean for the flotation effluent is 60 dynes/cm.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

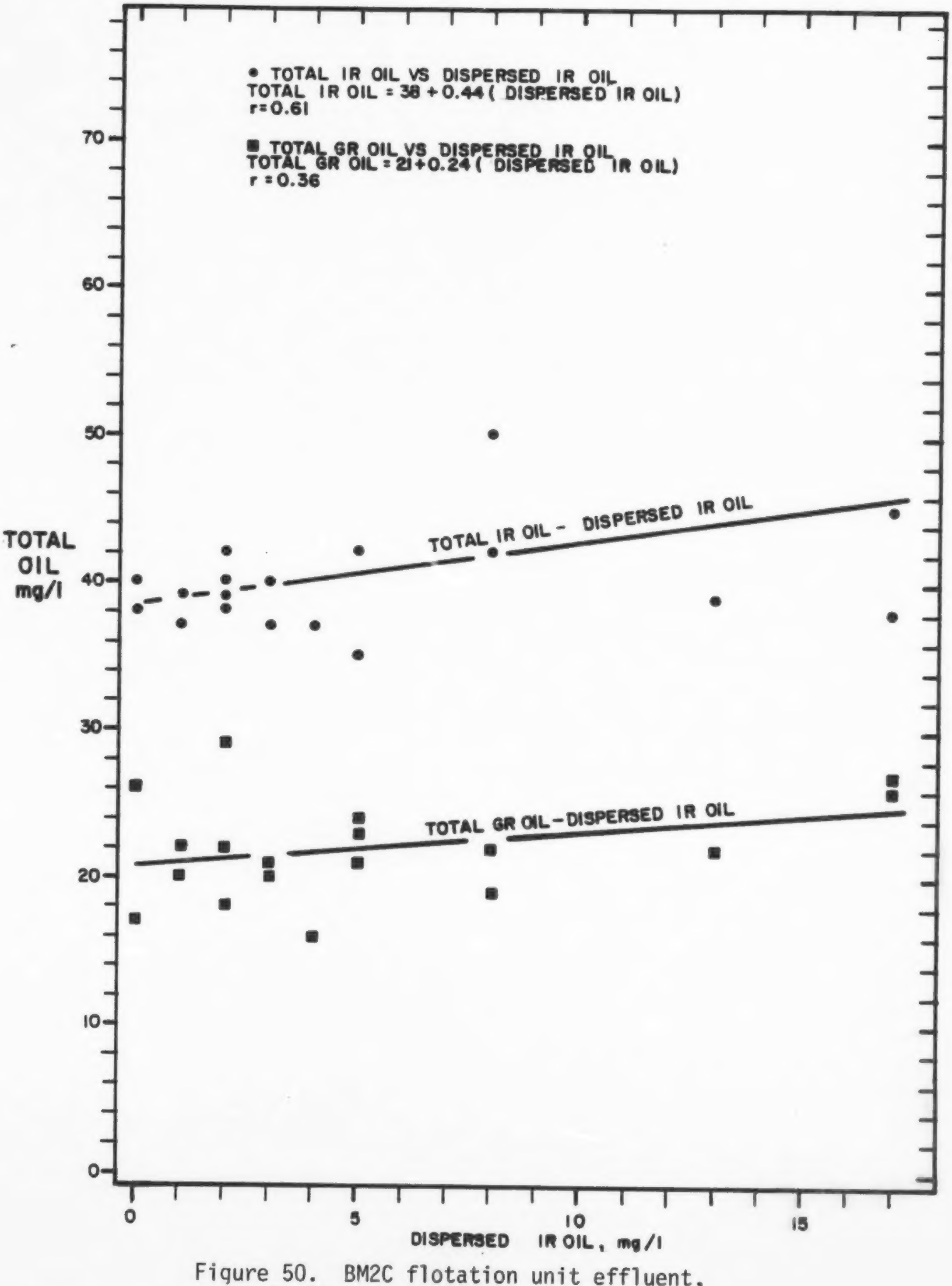


Figure 50. BM2C flotation unit effluent,
total oil - dispersed oil regression.

TYPING GUIDE SHEET

Eight of the ten flotation effluent surface tension test results were in the range of 57 to 64 dynes/cm. The other two results were 45 and 70 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 65 - 0.4\ (\text{Surface Tension})$$
$$r = -0.5$$

A decrease in IR-Oil of 0.4 mg/l is indicated for each one dyne/cm increase in surface tension.

The lowest surface tension measurement of 45 dynes/cm corresponded with the highest effluent IR-Oil measurement of 50 mg/l. The highest surface tension measurement of 70 dynes/cm corresponded with an IR-Oil measurement of 37 mg/l, 2 mg/l below the mean IR-Oil content.

The one lowest surface tension value was most significant in establishing the slope of the linear regression line.

Suspended Solids

Suspended solids test data are presented in Table 83 for major sampling points. Total suspended solids and Freon soluble suspended solids data were not obtained because of problems in completing the analyses.

A suspended solids summary for BM2C is presented in Table 84.

The data in Table 84 indicate that most of solids in the effluent were acid soluble. Both Freon insoluble and acid soluble solids increased through the system.

The effluent brine of BM2C had a yellowish-brown color which disappeared on acidification. The source of the color may have been oxidized iron compounds.

Figure 51 presents time-indexed plots of Freon insoluble suspended solids in the flotation unit influent and effluent, and of flotation effluent dispersed oil. All samples were taken at the same time, 0800 each day. The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when suspended solids are higher in the flotation unit influent or effluent.

As discussed in Section 18, the suspended solids test may not have adequate precision to provide meaningful results at the concentrations present in BM2C brine.

Filtered Brine

The filtered brine IR-Oil content of BM2C effluent was in the range of 22 to 71 mg/l with a mean of 51 mg/l. The mean IR-Oil content of unfiltered brine on BM2C was 40 mg/l for samples when filtered brine tests were also run.

EPA-287 (Cin.)
(4-76)

TABLE 83. BM2C SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8--i)					Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	-	-	8	7	1	-	-	-	-	-	-	-	28	28	0
02	08	-	-	18	15	3	-	-	8	8	0	-	-	21	21	0
03	08	-	-	62	15	47	-	-	19	14	5	-	-	23	23	0
04	08	-	-	9	9	0	-	-	11	11	0	-	-	26	26	0
05	08	-	-	10	8	2	-	-	0	0	0	-	-	25	25	0
06	08	-	-	15	15	0	-	-	12	12	0	-	-	20	20	0
07	08	-	-	16	16	0	-	-	72	72	0	-	-	8	8	0
08	08	-	-	10	6	4	-	-	7	7	0	-	-	5	5	10
09	08	-	-	9	0	9	-	-	8	0	8	-	-	71	71	0
10	08	-	-	28	26	2	-	-	220	179	41	-	-	192	153	39
Minimum		-	-	6	0	0	-	-	0	0	0	-	-	5	5	0
Maximum		-	-	62	26	47	-	-	220	179	41	-	-	192	153	39

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 84. BM2C SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 8--i	 9--i	 9--0
Freon Insoluble	18	40	42
Acid Soluble	12	34	38
Fixed	7	7	5

Note: Numbers do not check exactly because of rounding.

The fact that the measured oil content of filtered brine was consistently higher than that for unfiltered brine indicates a bias to the high side for the filtered brine tests run on BM2C.

Flotation Unit Performance

Figure 52 is a regression plot of IR-Oil in and out of the flotation unit. Figure 53 presents a regression plot of flotation unit effluent IR-Oil content and percent hydraulic loading. Figure 53 also presents a similar plot for gravity separator effluent.

Flotation effluent IR-Oil content is essentially independent of influent IR-Oil content. The slope of the linear regression line was only 0.008. Flotation effluent IR-Oil content was also essentially independent of hydraulic loading. The slope of the linear regression line was -0.02. Influent IR-Oil was in the range of 75 to 286 mg/l. Hydraulic loading was in the range of 18 to 39 percent of the design capacity.

Gravity Separator Performance

The sample point for the gravity separator (CPI) effluent is the same as for the flotation unit influent (9--i).

The CPI influent (8--i) and effluent (9--i) oil content test data are presented in Table 77. The effluent IR-Oil content was in the range from 75 to 286 mg/l and the mean was 158 mg/l.

Figure 53 presents a plot of CPI effluent IR-Oil content and percent hydraulic loading. The design loading rate used was 1,908 m^3/d based on removing 40-μm oil drops. Actual loading was in the range758 to 1,989 m^3/d, or 40 to 104 percent of design loading. Within this range, there is no apparent correlation between percent hydraulic loading and CPI effluent IR-Oil content. The calculated regression line actually has a negative slope.

The results of three susceptibility to separation test runs are presented in Table 85. The mean IR-Oil content for the three runs of 161 mg/l after one hour of settling is a little higher than the mean of 158 mg/l for thirty-eight CPI effluent tests.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

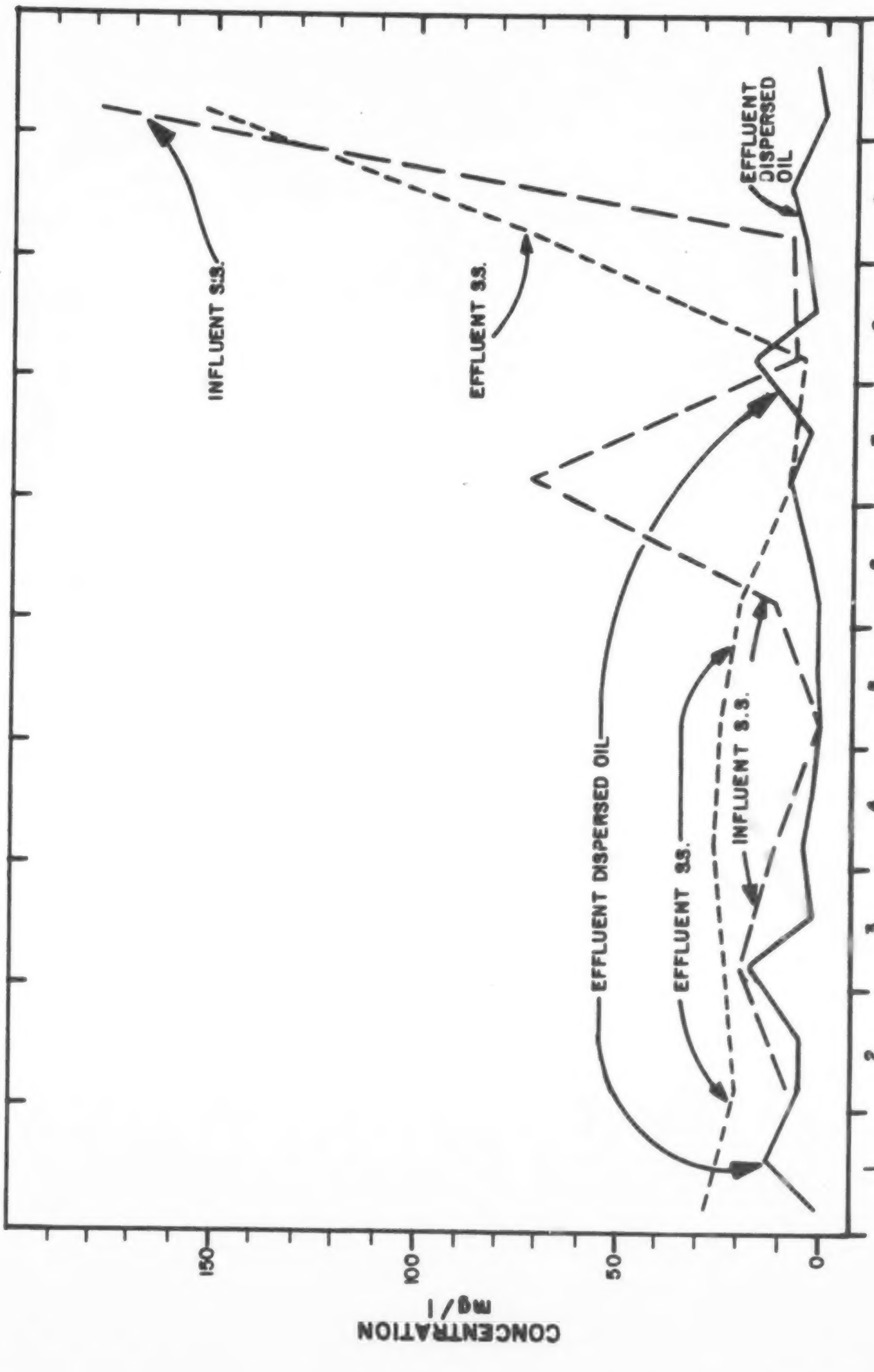


Figure 51. BM2C flotation unit Freon insoluble suspended solids.

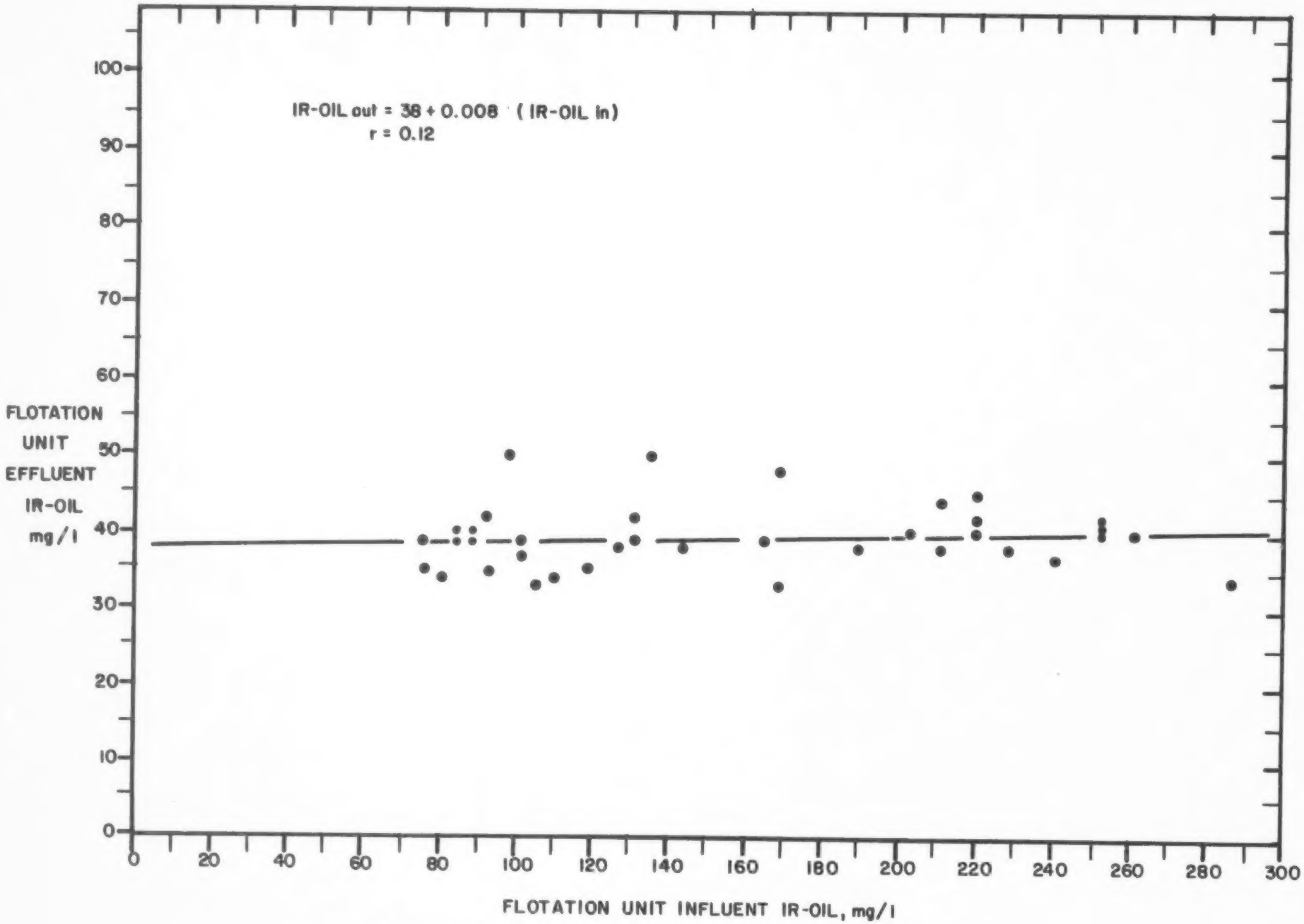


Figure 52. BM2C flotation unit in-out IR-oil regression.

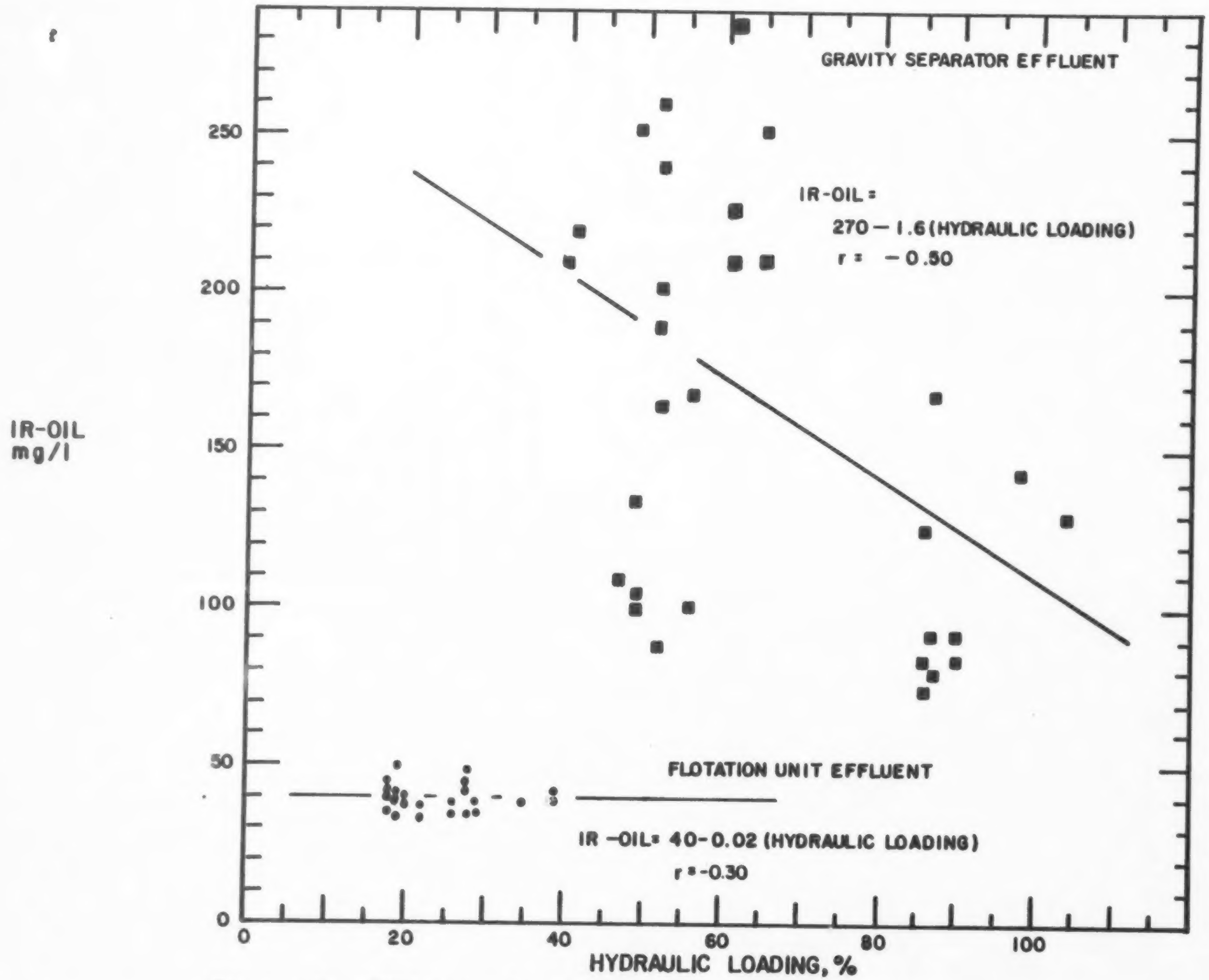


Figure 53. BM2C hydraulic loading - infrared oil regression

TABLE 85. BM2C SUSCEPTIBILITY TO SEPARATION TESTS ON GRAVITY SEPARATOR INFLUENT

	Settling time, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 5, 1000								
IR-Oil, mg/l	164	130	168	366	130	105	105	168
IR-Oil W/Silica Gel, mg/l	0	-	0	-	-	-	0	-
Test Number 2 Day 7, 1300								
IR-Oil, mg/l	538	378	261	261	244	168	160	521
IR-Oil W/Silica Gel, mg/l	479	-	202	-	-	-	101	-
Test Number 3 Day 8, 1300								
IR-Oil, mg/l	487	336	227	202	235	210	118	445
IR-Oil W/Silica Gel, mg/l	370	-	126	-	-	-	42	-
Average								
IR-Oil, mg/l	396	281	219	276	203	161	128	378
IR-Oil W/Silica Gel, mg/l	283	-	109	-	-	-	48	-

The data for Test Number 1 in Table 85 show significant differences in the oil separation rate of the gravity separator influent brine samples even over the span of the few minutes required to take the samples. Separation rate also varies from day to day.

The largest oil drop detected by the particle size test in the CPI effluent had a diameter of 35 μm.

At the time of the particle size test, the CPI separator was performing within the assumed design objective of removing 40- μm drops. The mean IR-Oil content of the CPI effluent was 158 mg/l even though the particle size measurements indicated removal of all drops larger than 35 μm.

Miscellaneous Brine Tests

All other brine test results for BM2C are listed in Tables 86, 87, 88, and 89. The results for the following tests were in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation for sample-to-sample variation in effluent oil content on BM2C. These parameters will be discussed in with respect to variations between platforms in Section 17.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on BM2C. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil test results are listed in Tables 90 and 91. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one or two and are of primary significance for comparisons between platforms.

Two equilibration tests were run, each at a different oil/water ratio.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil. Between-platform comparisons will be presented in Section 17.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 86. BM2C SUPPLEMENTARY BRINE TESTS

Sample time Day	Hour	Temperature, °C 8--i	 9--i	 9--0	pH 9--0	Specific gravity(1) 9--0
01	08	43.0	42.0	39.5	7.1	1.090
02	08	44.0	45.0	44.0	6.7	1.093
03	08	45.0	43.5	43.0	6.5	1.094
04	08	46.0	48.5	47.0	6.4	1.089
05	08	48.0	46.0	47.0	6.5	1.092
06	08	45.0	45.5	45.5	6.6	1.095
07	08	47.0	45.5	46.5	6.5	1.093
08	08	47.5	48.5	47.0	6.6	1.095
09	08	47.0	46.0	46.5	6.7	1.095
10	08	45.5	45.5	44.5	6.5	1.098
Mean		45.8	45.6	45.0	6.6	1.093
Minimum		43.0	42.0	39.5	6.4	1.089
Maximum		48.0	48.5	47.0	7.1	1.098

Note: Sample point identification numbers (8--i, 9--i, 9--0) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 87. BM2C BRINE TESTS AT MINOR SAMPLING POINTS

Sample time Day	Hour	IR-Oil, mg/l 5A20	 6--0	Temperature, °C 5A20	 6--0
03	08	1,030	240	46.0	42.0
06	08	303	84	45.5	44.5

Note: 5A20 is the low pressure separator effluent.
6--0 is the oil treater effluent.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
6-1/2"
9-1/8"

TABLE 88. BM2C SULFATE REDUCING BACTERIA

Sample time	Bacteria per milliliter
Low Pressure Separator - Out	0
Gravity Separator (CPI) - In	100-1,000
Gravity Separator (CPI) - Bottom	1,000-10,000
Flotation Unit - In	0
Flotation Unit - Out	10-100

Sample Day and Hour: 06 at 16

TABLE 89. BM2C IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	42,000
Potassium (K)	405
Calcium (Ca)	1,750
Magnesium (Mg)	360
Barium (Ba)	79
Chloride (Cl)	60,800
Sulfate (SO_4)	6
Alkalinity (as HCO_3)	555
Iron (Total)	5
Sulfide (as H_2S)	0.10
Total Dissolved Solids	
Summation	105,000
Gravimetric	114,000

Sample Day and Hour: 09 at 15

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 90. BM2C CRUDE OIL MISCELLANEOUS TESTS(1)

Sample time Day	Hour	Temperature °C	Specific(2) gravity	Surface tension(3) dynes/cm
01	08	32.5	0.835	26
02	08	37.5	0.836	25
03	08	37.5	0.830	25
04	08	40.5	0.828	23
05	08	42.0	0.827	24
06	08	40.5	0.830	24
07	08	40.5	0.829	22
08	08	41.5	0.831	29
09	08	40.0	0.831	24
10	08	38.5	0.832	25
Mean		39.1	0.831	25
Minimum		32.5	0.827	22
Maximum		42.0	0.836	29

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
09	15	4.02	3.41

	Equilibration at 82°C Brine TDS = 105,000 mg/l	
Oil/Water Ratio	4/1	2.64/1
IR-Oil, mg/l	8	8
IR-Oil W/Silica Gel, mg/l	6	6
IR-Oil Filtered Brine, mg/l	8	6

---

(1) Samples taken from oil treater.
(2) Specific gravity reported for temperature in table.
(3) Surface tension measured and reported at ambient temperatures from 21.2°C to 25°C.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTION HERE

TABLE 91. BM2C CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	410

Boiling range, °C	Percent recovered
Below - 200	61.1
200 - 250	22.6
250 - 300	13.2
300 - 350	2.4
350 - 400	0.6
400 - 450	0.1
450 - 500	0.0
Total	100.00

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
7/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

SECTION 10

PLATFORM ST131

GENERAL

The ten-day test program was conducted on Platform ST131 from March 16 through March 25, 1980. The operating company provided the transportation, accommodations, utilities, and operational information needed for a successful survey.

The test equipment was transferred by boat to Platform ST131 directly from Platform BM2C. High waves caused a one-day delay in unloading the equipment.

There were minor variations in production and water treating parameters during the survey period. However, the variations were not of a nature to cause a single planned sample to be lost.

FACILITIES AND OPERATIONS

Production From Wells

Sixteen wells were in production for at least one day during the survey period. Twelve wells produced continuously and the others intermittently.

Two wells flowed to the high-pressure separator. Ten wells flowed to the low-pressure separator. The other four wells were gas lifted to the low-pressure separator.

The estimated production based on well test data is 295 m^3/d (1,853 bpd) of oil, 138 m^3/d (870 bpd) of water, and 215,700 std m^3/d (7,623 Mcfd) of gas for wells producing on at least five days. The calculated water cut is 32 percent. The water cut varied significantly from day to day because one well producing more than half of the water flowed intermittently.

Sixty-four percent of the oil was gas lifted, and twenty-one percent of the water was gas lifted.

Production Process System

Figure 54 is a flow diagram of the ST131 production process system. Design and operating data on major vessels are presented in Table 92. Two wells flow to the high-pressure two-phase separator and all liquids then flow

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

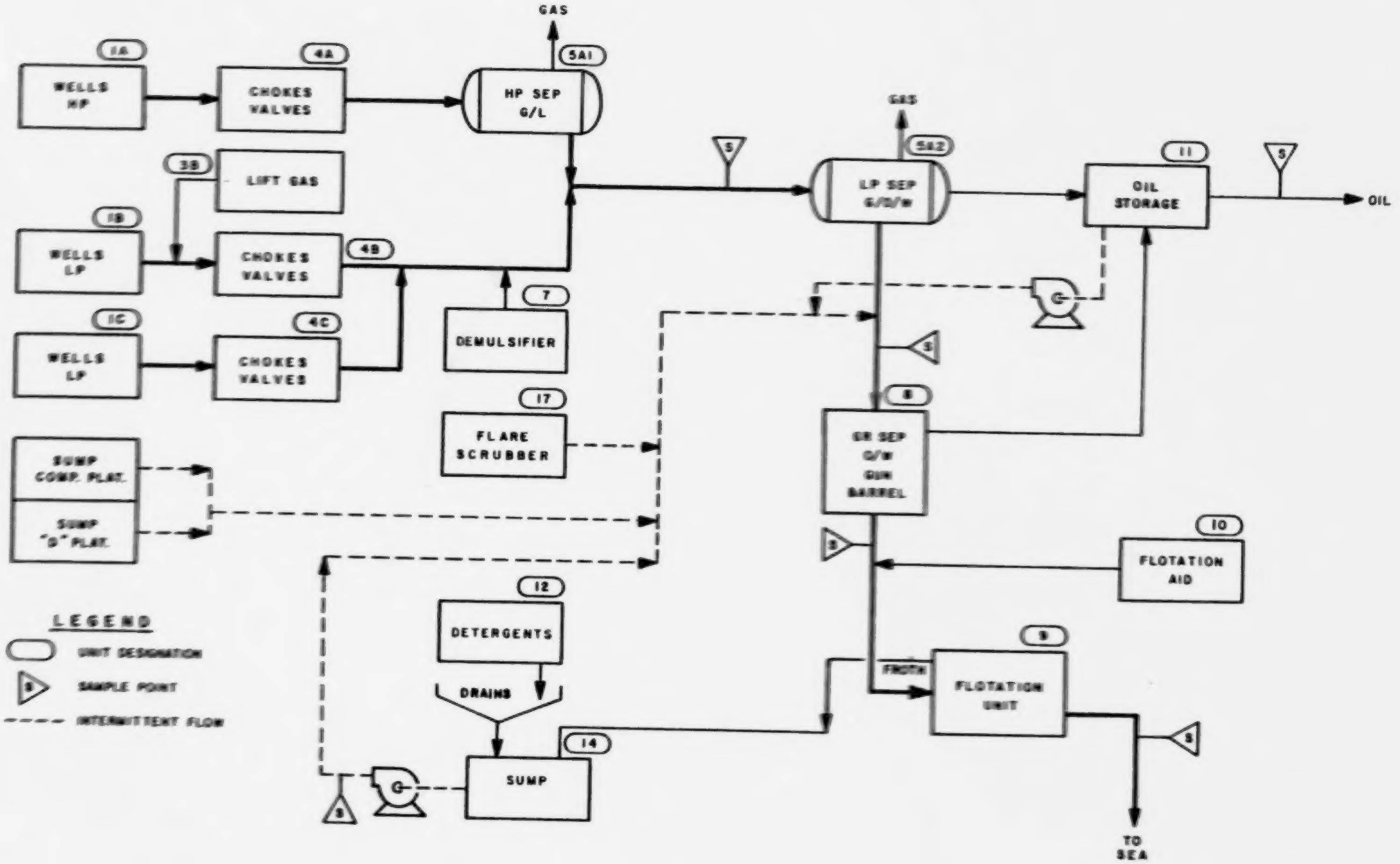

1A
WELLS HP
4A
CHOKES VALVES
5A1
HP SEP G/L
GAS
3B
LIFT GAS
1B
WELLS LP
CHOKES VALVES
4B
1C
WELLS LP
4C
CHOKES VALVES
7
DEMULSIFIER
17
FLARE SCRUBBER
SUMP COMP. PLAT.
SUMP "D" PLAT.
S
5A2
GAS
LP SEP G/O/W
11
OIL STORAGE
S
OIL
S
8
GR SEP O/W GUN BARREL
S
10
FLOTATION AID
12
DETERGENTS
DRAINS
14
SUMP
S
FROTH
9
FLOTATION UNIT
S
TO SEA
LEGEND
UNIT DESIGNATION
SAMPLE POINT
INTERMITTENT FLOW

Figure 54. Flow diagram, production process system, ST131.

TABLE 92. ST131 VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 10-1 5A1 High pressure 2-phase separator	 5A2 Low pressure 3-phase separator	 8 Gravity separator, gun barrel	 9 Flotation unit, mechanical, dispersed gas
Trade Name or Vessel Type	Horizontal Cylinder	Horizontal Cylinder	Rectangular	Wemco Model 56
Design Parameters				
Dimensions, m,(ft)				
Diameter, O.D.	-	1.8(6)	-	-
Length, S.S.	-	6.1(20)	-	-
Length	-	-	6.86(22.5)	5.70(18.7) (1)
Width	-	-	4.27(14)	1.31(4.3) (1)
Height	-	-	6.15(20.2)	0.85(2.8) (1)
Separation Surface Area, m^2,(ft^2)				
Total	-	-	29.3(315)	7.43(80)
Per Cell	-	-		1.86(20)
Separation Volume, m^3, (bbl)				
Total	-	-	170(1,070)	4.55(28.6)
Oil Phase	-	-	54(340)	
Water Phase	-	-	116(730)	
Number of Cells	-	-	-	4
Flow Rate, m^3/day,(bpd) (2)	-	-	-	1,638(10,300)
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2) (3)	-	-	-	881(515)
Recycle Rate, Percent of Flow	-	-	-	-
Retention Time, min.	-	-	-	4
Average Operating Parameters				
Temperature, $^oC(^oF)$	-	22.9(73)	22.8(73)	22.6(73)
Pressure, kPag(psig)	6,757(980)	517(75)	0	0
Flow Rate, m^3/d,(bpd) (2)	-	-	241(1,516)	111(698)
Flow Rate, Percent of Design (2)	-	-	-	7
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2) (2)	-	-	8.2(4.8)	60(35)
Recycle Rate, Percent of Flow	-	-	-	-
Froth Flow, Percent of Flow (2)	-	-	-	117

(1) Separation tank only.
(2) Based on effluent flow.
(3) Overflow rate is surface area divided by flow rate.

to the low-pressure three-phase separator.

All other wells flow, or are lifted, to the low-pressure separator. Oil flows from the low-pressure separator to a storage tank and brine flows to the gun barrel. The brine flows from the gun barrel to the flotation unit and then to discharge.

Miscellaneous drains are connected to sumps from which the fluids received are pumped back to the gun barrel. During the survey the only significant flow to sumps was the flotation unit skimmings. Minor flows to sumps occurred from washdown of curbed areas.

A flotation aid, Tretolite FR-81, was added to the influent of the flotation unit.

Figure 55 is a flow schematic for the water streams to and from the gun barrel and the flotation unit. The flow rate of the produced brine was monitored at the gun barrel inlet. The flotation unit skimmings flow was estimated based on time and rate of pumping of the sump pump. Flow rates at other points were calculated.

A nominal average water flow balance is presented in Figure 55. The flow rate of the flotation effluent and skimmings at each sampling time is presented later in this section.

The gun barrel receives oily water and provides for gravity separation of oil to prepare the water for flotation. The gun barrel on ST131 is identical to the one on ST177. A dimensional sketch of the ST177 gun barrel is presented in Section 8 in Figure 31.

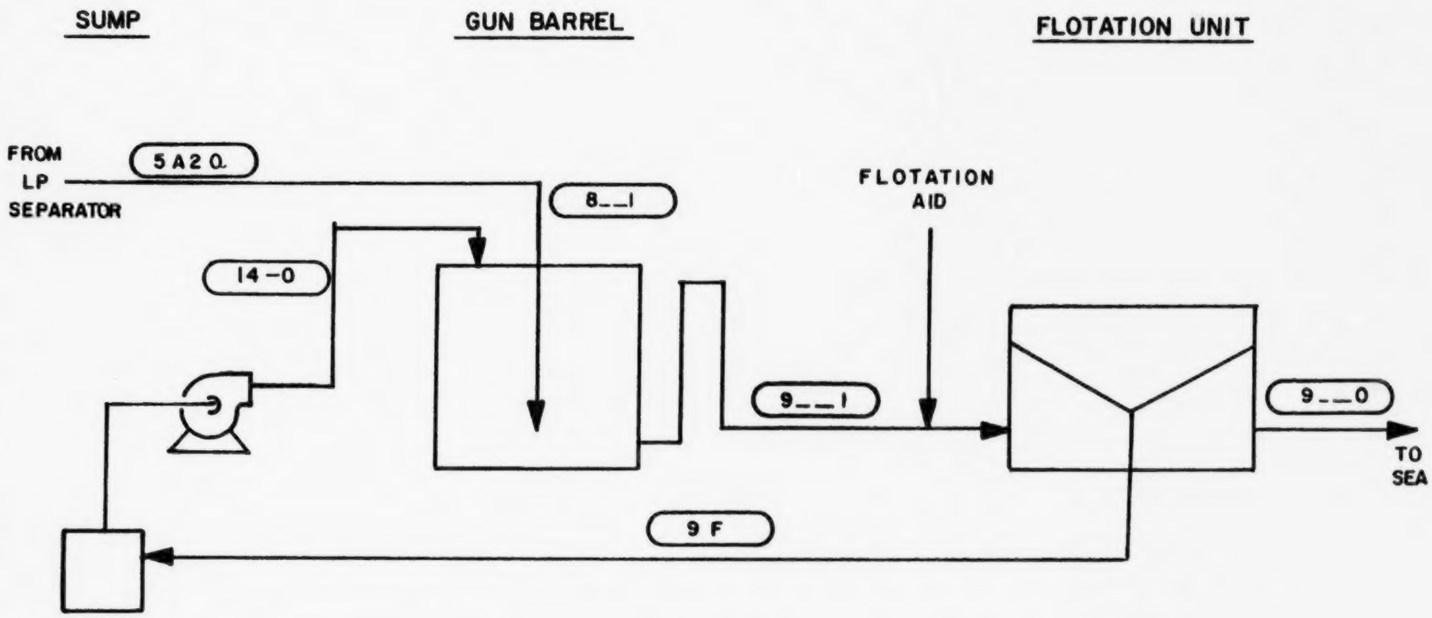
Based on the average flow from the gun barrel of 241 m^3/d the average residence time in the gun barrel is calculated to be 12 hours. This is a very conservative residence time for a gravity separator. However, the produced brine portion of the flow is discharged through a distributor near the bottom of the tank. There is significant potential for short-circuiting to the outlet which is also near the bottom. There is no simple way to estimate actual residence time or separation capability of the ST131 gun barrel.

The flotation unit (Wemco 1 + 1, Model 56) on ST131 is the same type as the one on SP65B, a four-cell unit with mechanical gas dispersion. This type unit was described in Section 6 and depicted in Figure 6.

The design flow for the ST131 flotation unit is 1,638 m^3/d (10,300 bpd). The average operating flow was 111 m^3/d (698 bpd) or 7 percent of design flow. The skimmings flow was 130 m^3/d (818 bpd), or 117 percent of the effluent flow.

SITE SPECIFIC TEST PROGRAM

The planned sampling and testing schedule for ST131 brine tests is presented in Table 93. The sample point, number of samples in ten days, and the time of day for each sample are listed.


SUMP
GUN BARREL
FLOTATION UNIT
FROM
LP
SEPARATOR
5A2O
8__1
14-0
FLOTATION
AID
9__1
9__0
TO
SEA
9 F

WATER FLOW		5A20	14-0	9F	8__1	9__1	9__0
	m^3/d	111	130	130	111	241	111
	bpd	698	818	818	698	1516	698

Figure 55. ST131 water handling system flow schematic.

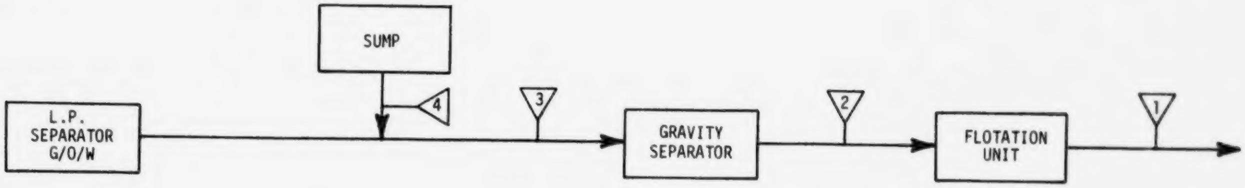


TABLE 93. ST131 TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS							
	1		2		3		4	
	9--0		9--i		8--i		14--0	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests								
Infrared Oil	20	8,13	20	8,13	20	8,13	2	8
Temperature	10	8	10	8	10	8	2	8
pH	10	8	-	-	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-	-	-
Water Surface Tension(2)	10	8	-	-	10	8	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	10	8	-	-
IR-Oil Filtered Brine	20	8,13	-	-	10	8	-	-
Susceptibility to Separation(3)	-	-	-	-	3	13	-	-
Laboratory Tests								
Gravimetric Oil	40	8,10,13,15	10	8	-	-	-	-
Suspended Solids	10	8	10	8	10	8	-	-
Ionic Analysis	1	(1)	-	-	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.						-	-
Particle Size Distribution(4)	3	13	3	13	3	13	-	-

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/silica gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/silica gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

In addition to the brine tests, the following tests were run on ST131 crude oil: temperature, specific gravity, surface tension, viscosity, equilibration, and boiling range distribution.

OPERATIONAL DATA AND OBSERVATIONS

Measurements and observations by the survey team and reports and records provided by the operator are presented in this subsection.

Flow Monitoring

The produced brine flow into the gun barrel was monitored continuously using a Doppler meter with a sensor that clamped on the outside of the pipe. Short term flow variations over a few seconds were so wide that the strip chart record was not readable. However, it was possible to confirm that the average flow estimate by well test data was reasonably accurate. This was done by visually reading the flow indicator on the monitor each 15 seconds for 10 minutes and calculating an average flow.

The flow monitor was particularly useful in detecting the intermittent flow from high-water-producing well D-15.

A flow rate for the flotation effluent is reported for each sampling time in Table 94. These flow rates are calculated by subtracting other known flows from the monitored flow as discussed earlier.

Well Test Data

The well test data provided by the operator are listed in Table 95. The data are grouped according to whether the flow was to the high-pressure separator or low-pressure separator. The data for wells flowing to the low-pressure separator are further subdivided according to whether the well was flowing or was gas lifted.

Pressure Drops Through System

The pressures of the high-pressure separator and the low-pressure separator were recorded twice per day. The flowing tubing pressure for each well was obtained from well test data. The ranges for these pressures are presented in Table 96. The magnitude of pressure drops between different points in the system are also listed.

Chemical Addition

Two chemicals were added continuously by small metering pumps at the average rates listed in Table 97.

The addition rate of the demulsifier was quite uniform for the ten-day period. Sixteen of eighteen flow measurements were from 3.3 to 3.8 dm^3/d. The other two were 4.7 dm^3/d.

TABLE 94. ST131 MAJOR BRINE TESTS

Sample time		Gravity separator influent (8--1)					Flotation unit influent (9--1)		Flotation unit effluent (9--0)							
		IR-Oil	IR-Oil w/silica gel "Dispersed"	IR-Oil w/silica gel "Soluble"	Filtered brine IR-Oil	Surface tension	GR-Oil	IR-Oil	GR-Oil	IR-Oil	IR-Oil w/silica gel Dispersed	IR-Oil w/silica gel Soluble	Filtered brine IR-Oil	Surface tension	Flow rate Out	Flow rate Skimmings
Day	Hour	mg/l	mg/l	mg/l	mg/l	dynes/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	7,891	7,052	839	218	47	175	260	11	27	1	26	39	47	90	33
01	10	-	-	-	-	-	-	-	7	-	-	-	-	-	90	33
01	13	2,686	-	-	-	45	-	361	5	44	16	28	49	-	190	33
01	15	-	-	-	-	-	-	-	4	-	-	-	-	-	190	33
02	08	2,728	2,477	251	56	54	259	550	50	76	47	29	44	47	181	5
02	10	-	-	-	-	-	-	-	43	-	-	-	-	-	181	153
02	13	2,141	-	-	-	57	-	718	34	64	36	28	56	-	181	153
02	15	-	-	-	-	-	-	-	17	-	-	-	-	-	181	153
03	08	10,284	4,617	5,667	63	35	479	798	13	41	9	32	41	53	90	142
03	10	-	-	-	-	-	-	-	12	-	-	-	-	-	190	142
03	13	20(1)	-	-	-	42	-	445	10	37	4	33	44	-	190	142
03	15	-	-	-	-	-	-	-	9	-	-	-	-	-	190	142
04	08	15(1)	-	-	59	38	245	407	14	21	0	21	36	67	101	147
04	10	-	-	-	-	-	-	-	12	-	-	-	-	-	150	142
04	13	881	-	-	-	43	-	541	3	26	0	26	40	-	150	142
04	15	-	-	-	-	-	-	-	1	-	-	-	-	-	150	142
05	08	4,659	3,946	713	44	56	444	756	4	25	0	25	12	66	188	109
05	10	-	-	-	-	-	-	-	2	-	-	-	-	-	80	109
05	13	20(1)	-	-	-	34	-	239	57	92	88(A)	4(A)	40	-	80	109
05	15	-	-	-	-	-	-	-	7	-	-	-	-	-	80	109
06	08	24(1)	-	-	688	33	170	269	20	27	0	27	40	62	82	229
06	10	-	-	-	-	-	-	-	6	-	-	-	-	-	82	229
06	13	84(1)	-	-	-	33	-	285	5	26	0	26	46	-	82	229
06	15	-	-	-	-	-	-	-	3	-	-	-	-	-	82	229
07	08	35(1)	-	-	84	28	173	277	11	29	0	29	42	62	82	229
07	10	-	-	-	-	-	-	-	18	-	-	-	-	-	82	229
07	13	8(1)	-	-	-	39	-	197	18	29	0	29	66	-	82	229
07	15	-	-	-	-	-	-	-	7	-	-	-	-	-	82	229
08	08	45(1)	-	-	923	36	159	231	11	30	0	30	54	70	82	218
08	10	-	-	-	-	-	-	-	10	-	-	-	-	-	82	218
08	13	22(1)	-	-	-	26	-	344	7	29	0	29	64	-	82	218
08	15	-	-	-	-	-	-	-	2	-	-	-	-	-	82	218
09	08	58(1)	-	-	151	34	312	504	1	24	0	24	44	68	82	11
09	10	-	-	-	-	-	-	-	4	-	-	-	-	-	82	27
09	13	10(1)	-	-	-	26	-	185	11	33	0	33	47	-	82	27
09	15	-	-	-	-	-	-	-	4	-	-	-	-	-	82	218
10	08	227	143	84	78	56	82	222	1	28	0	28	42	63	55	5
10	10	-	-	-	-	-	-	-	11	-	-	-	-	-	55	5
10	13	130	-	-	-	59	-	126	22	31	0	31	50	-	55	5
10	15	-	-	-	-	-	-	-	12	-	-	-	-	-	55	5
Minimum		130	143	84	44	26	82	126	1	21	0	21	12	47	55	5
Maximum		10,284	7,052	5,667	923	59	479	798	57	92	47	33	66	70	190	229

(1) Oil content reported in percent as measured by the water cut test.
(A) Not included in statistical analysis. Appears inconsistent with all other IR-Oil w/silica gel tests.

TABLE 95. ST131 WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig SIBHP	Pressure, psig FTP	Choke size 1/64 in.	API gravity	Days of production
Flowing to High Pressure Separator											
C10-	E-2C	9,795	900	24	0	0	3,084	2,100	9	50.5	All
D-5-	C-7G	6,870	1,400	11	2	0	1,950	1,800	12	-	All
Total (Average)		-	2,300	35	2	-	-	-	-	(50.5)	
Flowing to Low Pressure Separator											
C-9D	E-GA	10,170	165	159	159	0	3,645	300	17	32.9	All
D15-	D-5E	7,342	-	0	450	0	2,697	-	-	-	1,2,3,4,5
G-2-	C-3K	5,730	1,900	18	0	0	2,496	1,880	14	-	All
I-2-	E-9N	8,660	64	95	11	0	3,822	320	12	34.9	1-8,10
J-2D	C-7C	6,975	1,000*	0*	0*	0*	1,472	1,075	13	-	1
J-3-	D11E	7,005	620*	0*	0*	0*	1,932	550	15	-	1
J-4D	C-3F	6,480	340	90	0	0	2,191	850	16	34.1	All
J-8-	C-3I	6,780	1,995	0	0	0	1,997	1,500	18	-	All
J14-	D10F	7,835	90	46	68	0	3,473	250	12	37.5	All
J14D	D-3F	7,370	250	221	0	0	-	950	12	38.7	All
Total (Average)		-	4,804	629	688	-	-	-	-	(35.6)	
Flowing Total		-	7,104	664	690	-	-	-	-	(38.1)	
Gas Lift to Low Pressure Separator											
C-3-	E-9A	10,600	200	395	0	950	2,413	225	48	34.6	All
C-7D	D-3G	7,465	19	47	31	821	1,764	240	64	29.4	All
J-7-	D-2D	-	60	148	0	780	3,120	225	48	36.7	All
J-9-	E-2A	8,375	240	599	149	620	2,233	290	64	37.6	All
Total (Average)		-	519	1,189	180	3,171				(34.6)	
Combined Total (Average)		-	7,623	1,853	870	-	-	-	-	(36.7)	

* Not included in average or total.

TABLE 96. ST131 PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Flowing Tubing Pressure	1,550-12,960 (225-1,880)	chokes, valves, pipes	960-12,480 (140-1,810)(1)
High Pressure	6,380-6,890 (925-1,000)	control valve, pipes	5,790-6,410 (840-930)
Low Pressure Separator	480-590 (70-85)	control valve, pipes	480-590 (70-85)
Gun Barrel	0 0		

(1) Minimum and maximum pressure drops are to the low-pressure separator. Does not include well C-10 flowing to the high-pressure separator.

TABLE 97. ST131 CHEMICAL ADDITION

Chemical	Addition point	Addition rate	
		dm^3/d	ppmv(1)
Tretolite RP-101 (Demulsifier)	Low pressure well manifold	3.8	34
Tretolite FR-81 (Flotation aid)	Flotation unit inlet	14	126

(1) Based on average produced brine flow of 111 m^3/d.

The addition rate of the flotation aid chemical was also relatively uniform. Nineteen of twenty-four measurements were between 10 and 17 dm^3/d. The afternoon of the tenth day the measured rate was 7.6 dm^3/day. The flotation chemical feed pump stopped pumping from 1230 to 1300 on Day 1. It also stopped pumping during the night of Day 1 and was restarted at 0800 on Day 2.

A detergent, Great Southern GS-1011, is occasionally used to wash down curbed areas on ST131.

Observations and Operator Reports

The purpose of this subsection is to describe variations in operations or any known non-routine event that could influence effluent brine oil content.

Numerous changes in brine flow rate occurred because of changes in which wells were producing. The changes were described in the subsections on Flow Monitoring and Well Test Data.

Numerous changes occurred in flotation unit skimmings rate. The skimmings rates for each sampling time are listed in Table 94.

Interruptions in flotation chemical feed were described in the immediately preceding subsection. At 0800 on Day 2, when the chemical feed was off, it was observed that the foam in the flotation unit was a few inches below the skimming weirs. It is not known how long this condition existed.

On Days 3, 4, 5, 6, 7, 8, and 9, high concentrations of oil were discharged from the low-pressure separator to the gun barrel. As listed in Table 94, samples contained from 8 to 84 percent oil, rather than 1 percent or less. The reason was that the low-pressure separator was operated with a low oil/water interface level.

Detergent GS-1011 was used to wash curbed areas. One wash down using several cubic decimeters of detergent was at 0800 on Day 10. The operator expected a decrease in foam level in the flotation unit but this was not observed. Also, none of the test results appeared to be affected.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables for ST131 are interspersed in the text.

Effluent Oil Content

Table 94 presents a listing of oil content test results for the major points. Figure 56 is a plot of GR-Oil in and out of the flotation unit versus time for the ten-day period. Figure 57 presents a similar plot for IR-Oil.

The tabulated data and the time-indexed plots show that effluent oil content is relatively consistent from sample to sample. However, there are oil content peaks on Day 2 and Day 5. The flotation chemical feed pump stopped during the night for an unknown period of time before the 0800 sample on Day 2 was taken. The pump was restarted just after the sample was taken. No reason is known for the high oil content measurements on Day 5 at 1300.

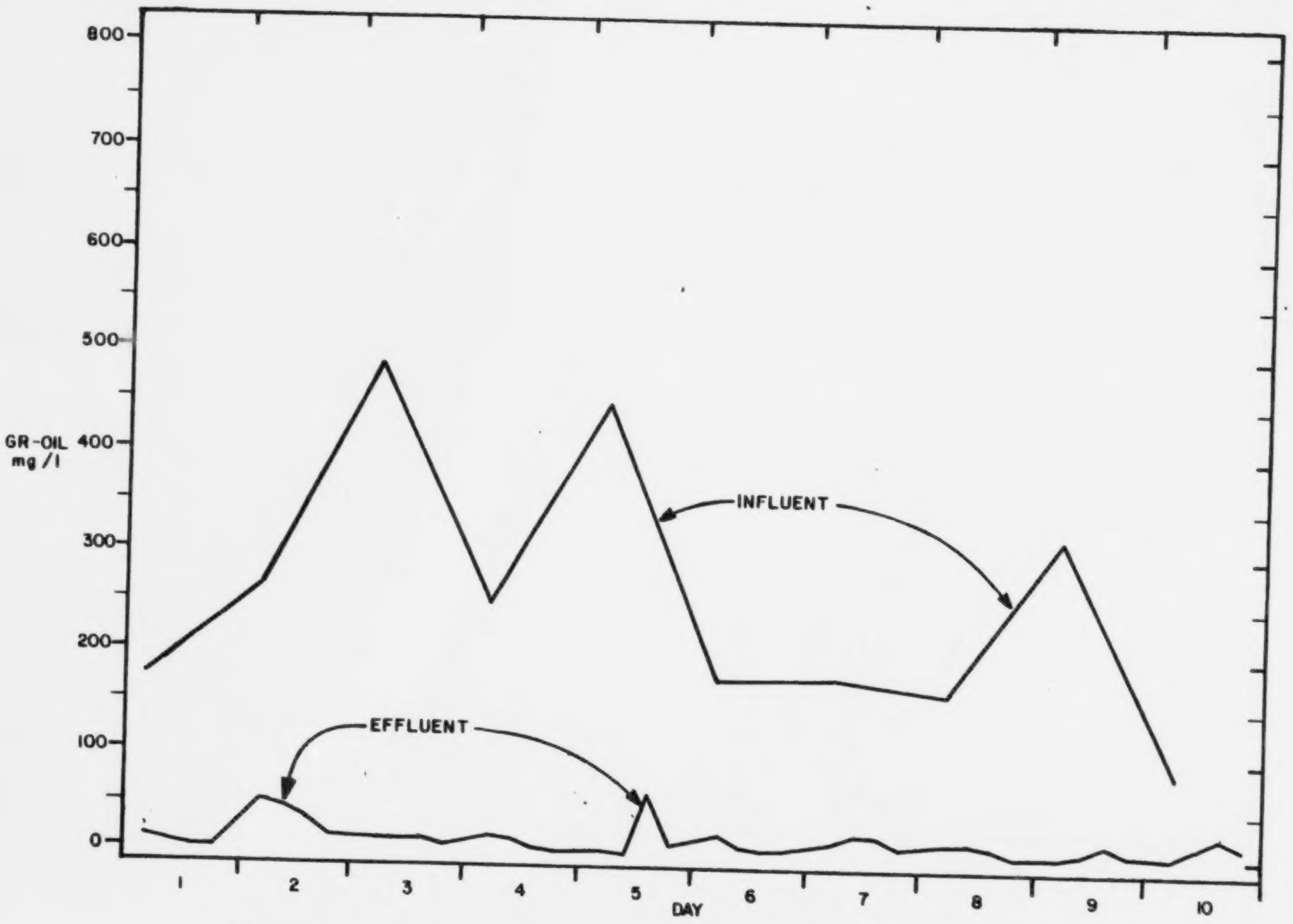


Figure 56. ST131 flotation unit performance, GR-oil vs time.

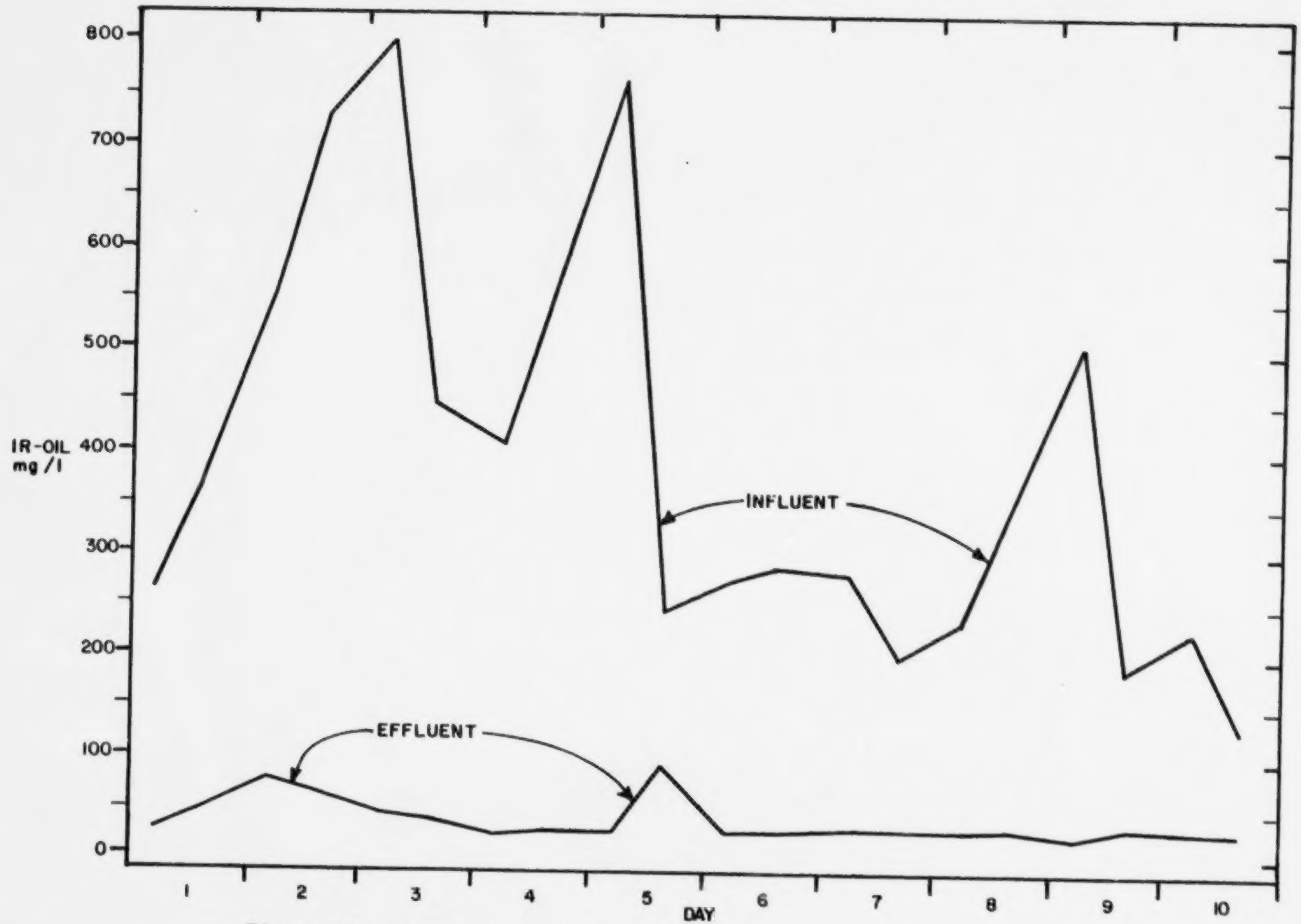


Figure 57. ST131 flotation unit performance, IR-oil vs time.

The ranges of test results are as follows:

Flotation Effluent GR-Oil - 1 to 57 mg/l,
Flotation Effluent IR-Oil - 21 to 92 mg/l,
Flotation Influent GR-Oil - 81 to 479 mg/l,
Flotation Influent IR-Oil - 126 to 798 mg/l.

Flotation unit effluent oil content histograms are presented in Figure 58 and Figure 59. Figure 60 is a regression plot of GR-Oil versus IR-Oil. Paired GR-Oil and IR-Oil samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Table 98 presents a summary comparison of test results by the two methods.

The data in Table 98 and the histograms illustrate that IR-Oil is consistently higher than the GR-Oil. However, the data in Table 98 and the scatter in the regression plot, Figure 60, indicate that there is not a uniform difference in paired tests by the two methods.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 94. A summary of these test results is presented in Table 99.

On average, 82 percent of the oil in the effluent was soluble oil and 18 percent was dispersed. Thirteen of nineteen samples did not contain any dispersed oil.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 61. Extrapolation of the regression lines to zero dispersed oil indicates a residual IR-Oil of 28 mg/l and a residual GR-Oil of 9 mg/l after all dispersed oil has been removed.

The mean soluble oil content of the gravity separator influent was 1,511 mg/l for five tests. The range was 84 to 5,667 mg/l. The range is so wide and the average so high that these test results are in question as giving an accurate indication of soluble oil in the gravity separator influent.

Surface Tension

All surface tension test results are reported in Table 94. The mean surface tension of the gravity separator influent is 41 dynes/cm and the mean for the flotation effluent is 61 dynes/cm.

The flotation effluent surface tension test results were in the range of 47 to 70 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 107 - 1.24\,(\text{Surface Tension})$$
$$r = -0.65$$

EPA-287 (Cin.)
(4-76)

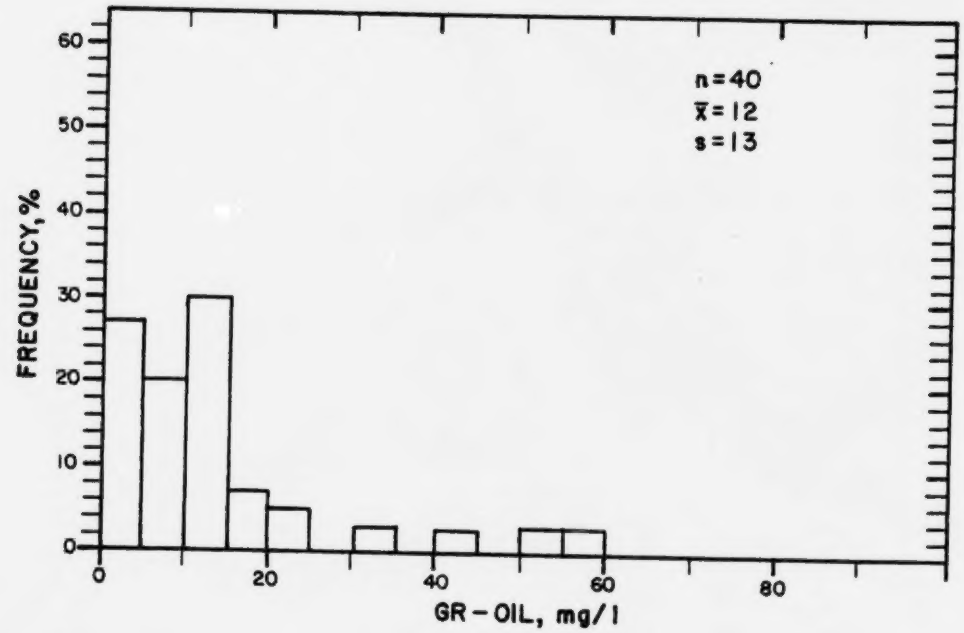


Figure 58. ST131 flotation unit effluent, GR-oil histogram.

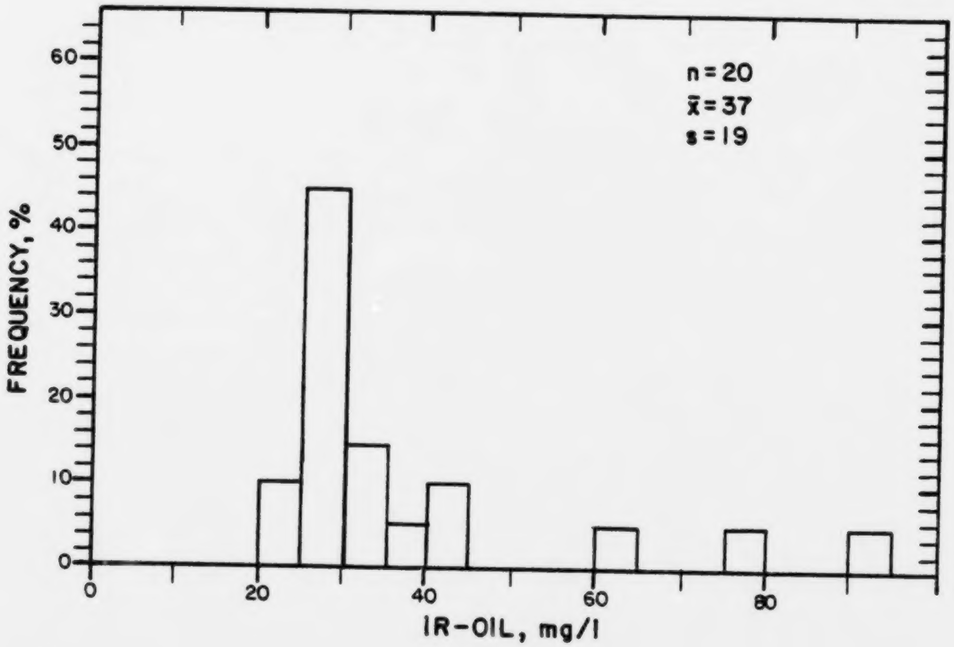


Figure 59. ST131 flotation unit effluent, IR-oil histogram.

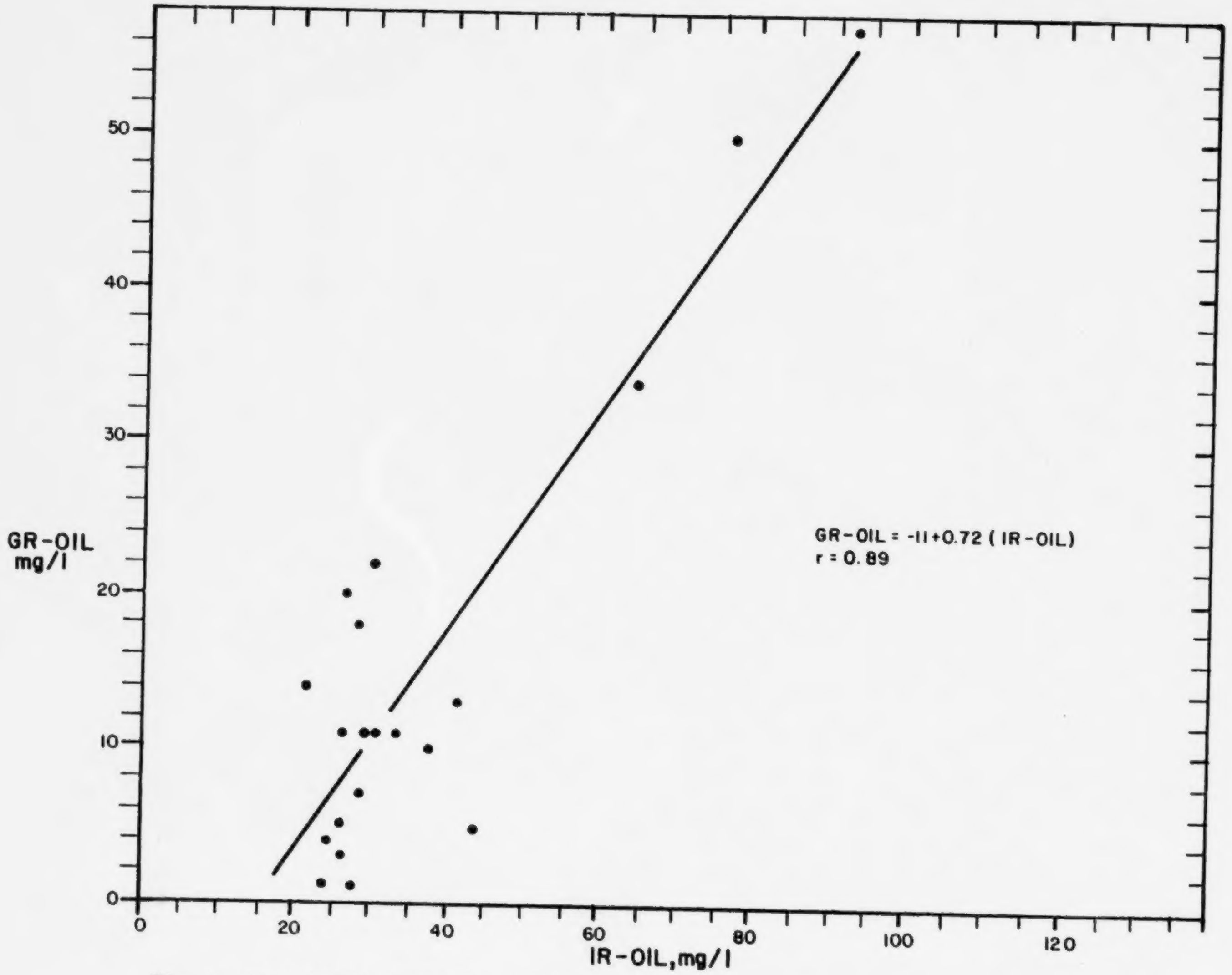


Figure 60. ST131 flotation unit effluent, infrared-gravimetric regression.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 98. ST131 FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	40	20
Mean, ($\bar{x}$), mg/l	12	37
Minimum, mg/l	1	21
Maximum, mg/l	57	92
Standard Deviation, (s), mg/l	12.8	18.8
	Paired tests	
Number, (n)	20	
Mean of Differences, ($\bar{\Delta}$), mg/l	21.55	
Standard Deviation, (s_Δ), mg/l	8.7	

TABLE 99. ST131 SOLUBLE OIL SUMMARY

	Flotation effluent		
Analysis or test	Range mg/l	Mean mg/l	Proportion of total, percent
IR-Oil$^{(1)}$	21-76	34	100
Dispersed Oil	0-47	6	18
Soluble Oil	21-33	28	82

(1) Includes only 19 test results when IR-Oil w/Silica Gel tests were obtained on same sample.

A decrease in IR-Oil of 1.24 mg/l is indicated for each 1 dyne/cm increase in surface tension.

Suspended Solids

Suspended solids test results are listed in Table 100 for major sampling points. A suspended solids summary for ST131 is presented in Table 101.

The data in Table 101 indicate a decrease in suspended solids through the system with minor exceptions. Acid soluble suspended solids apparently increased through the gravity separator, 8--i to 9--i. The reduction of Freon soluble suspended solids in the flotation unit of 1 mg/l is insignificant in relation to the accuracy of the test.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

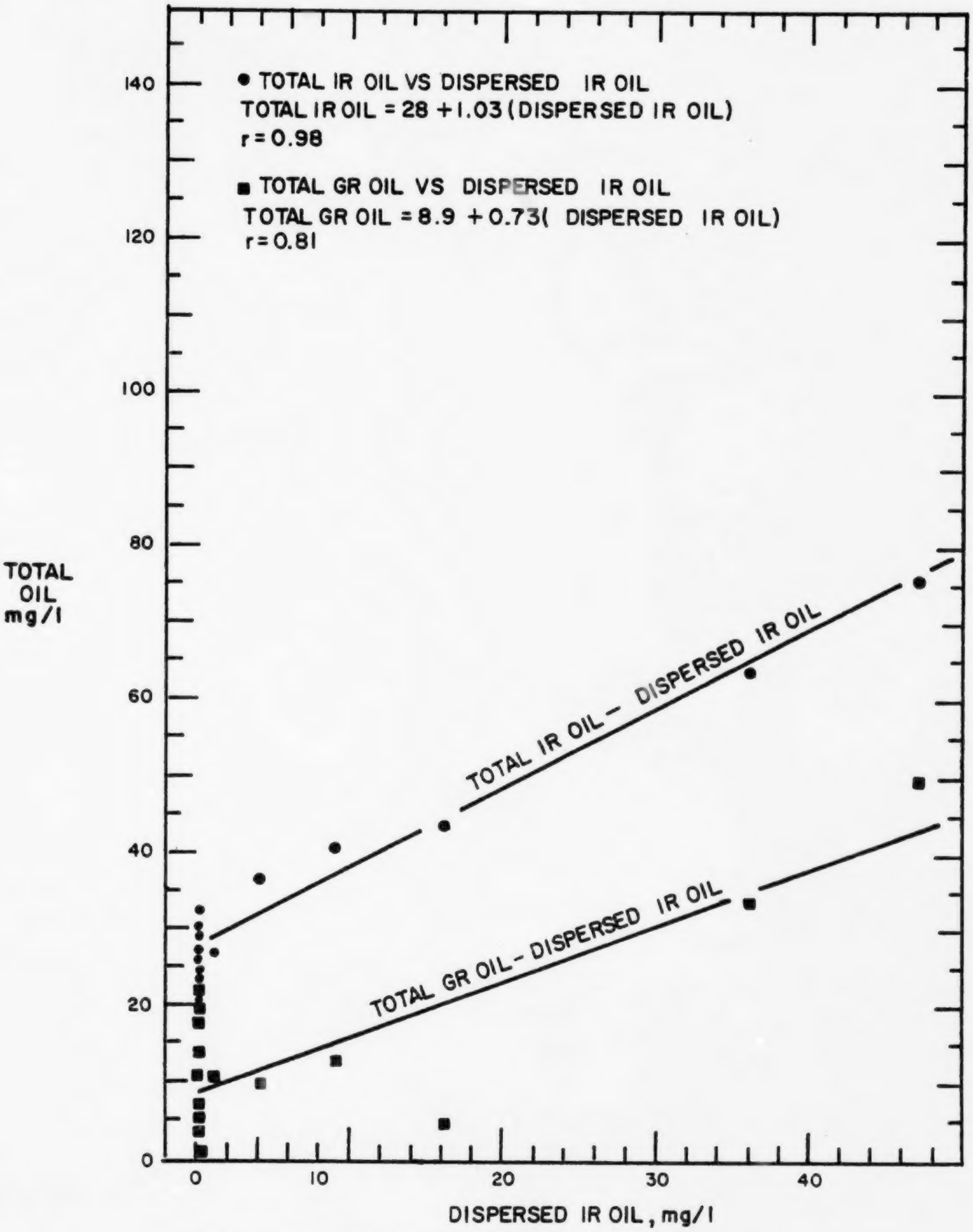


Figure 61. ST131 flotation unit effluent, total oil - dispersed oil regression.

TABLE 100. ST131 SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8--i)					Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	488	371	117	24	93	60	4	56	5	51	9	1	8	7	0
02	08	573	330	243	36	208	60	42	19	3	16	47	30	18	9	8
03	08	248	216	32	14	18	62	23	39	12	27	6	5	2	3	0
04	08	(1)	(1)	(1)	(1)	(1)	73	43	30	0	42	249	234	14	26	0
05	08	72	41	31	7	23	85	45	40	24	17	15	2	13	13	0
06	08	537	389	147	42	106	52	39	13	12	1	30	19	11	11	0
07	08	(1)	(1)	(1)	(1)	(1)	295	32	263	198	64	25	0	25	23	2
08	08	(1)	(1)	(1)	(1)	(1)	53	34	19	10	9	5	7	1	1	0
09	08	(1)	(1)	(1)	(1)	(1)	71	40	31	8	23	11	7	4	0	4
10	08	21	18	3	3	0	24	19	5	5	0	6	4	2	2	0
Minimum		21	18	3	3	0	24	4	5	0	0	5	0	1	0	0
Maximum		573	389	243	42	208	295	45	263	198	64	249	234	25	26	8

(1) Filters plugged by oil before an adequate volume of water was filtered for the test (less than 60 ml).

TYPING GUIDE SHEET

TABLE 101. ST131 SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 8--i	 9--i	 9--0
Total	323	84	40
Freon Soluble	228	32	31
Freon Insoluble	96	52	10
Acid Soluble	21	28	10
Fixed	75	25	1

Figure 62 presents time-indexed plots of Freon insoluble suspended solids in the flotation unit influent and effluent, and of flotation effluent dispersed oil. All samples were taken at the same time, 0800 each day. The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when suspended solids are higher in the flotation unit influent or effluent.

The Freon insoluble suspended solids content of the effluent is low, 10 mg/l. Two tests on the same sample could differ by more than 10 mg/l as discussed in Section 18. This degree of variability could mask any correlation with effluent oil content.

Filtered Brine

The filtered brine IR-Oil content of ST131 effluent was in the range of 12 to 66 mg/l with a mean of 45 mg/l. The mean IR-Oil content of unfiltered brine on ST131 was 37 mg/l for samples when filtered brine tests were also run.

The fact that the mean oil content of filtered brine was higher than that for unfiltered brine indicates a bias to the high side for the filtered brine tests run on ST131.

Flotation Unit Performance

Figure 63 is a regression plot of IR-Oil in and out of the flotation unit. Figure 64 is a regression plot of flotation unit effluent IR-Oil content and percent hydraulic loading.

Flotation effluent IR-Oil content increases gradually as influent IR-Oil content increases. The slope of the linear regression line was only 0.016. The correlation coefficient of 0.17 indicates a very limited correlation.

The hydraulic loading of the flotation unit was in the range from 3.4 percent to 11.6 percent of the design capacity. The plot in Figure 64 indicates an increase in IR-Oil with an increase in hydraulic loading. However, the maximum loading of 11.6 percent is so low that the data are of limited

EPA-287 (Cin.)
(4-76)

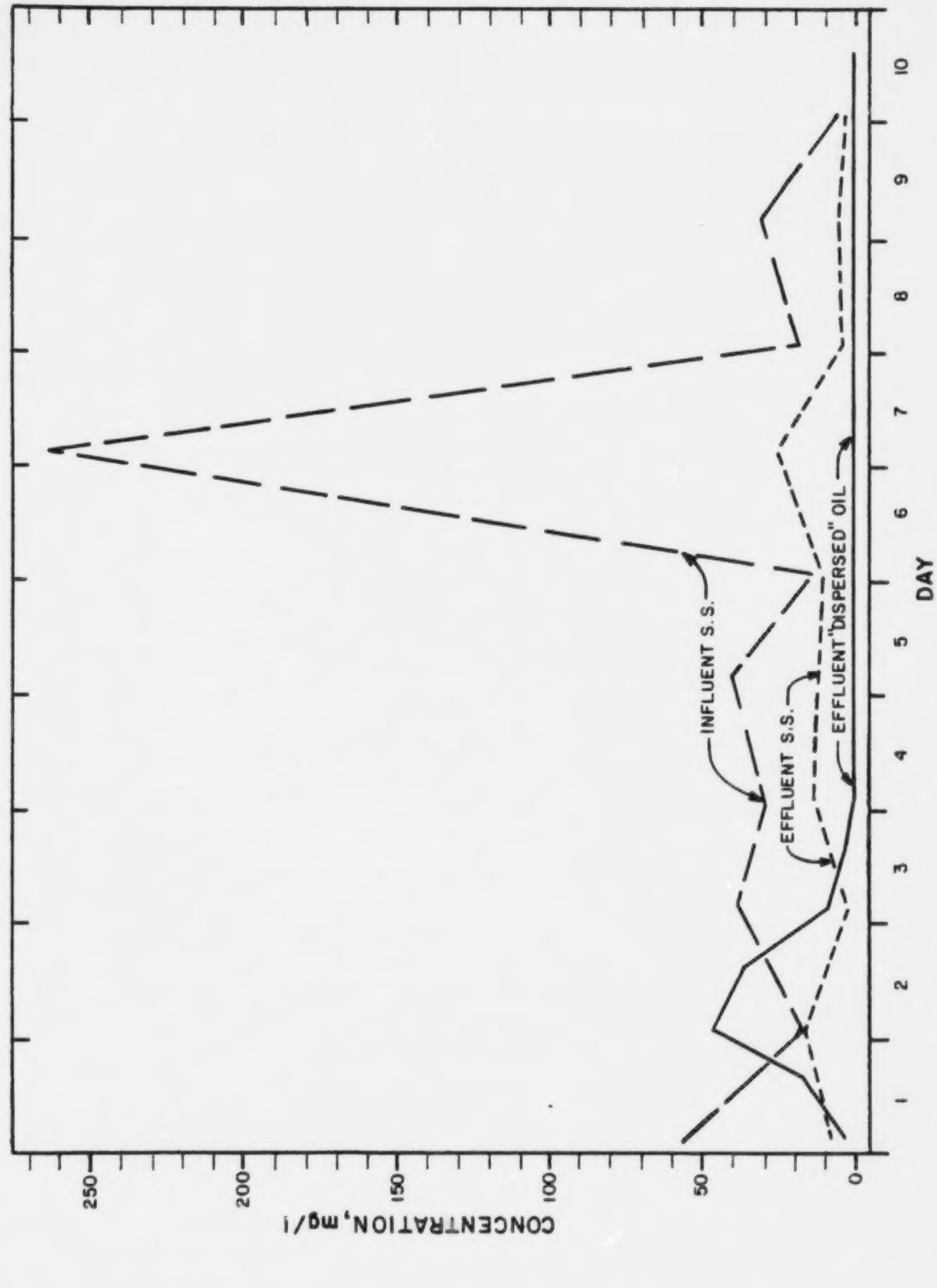


Figure 62. ST131 flotation unit Freon insoluble suspended solids.

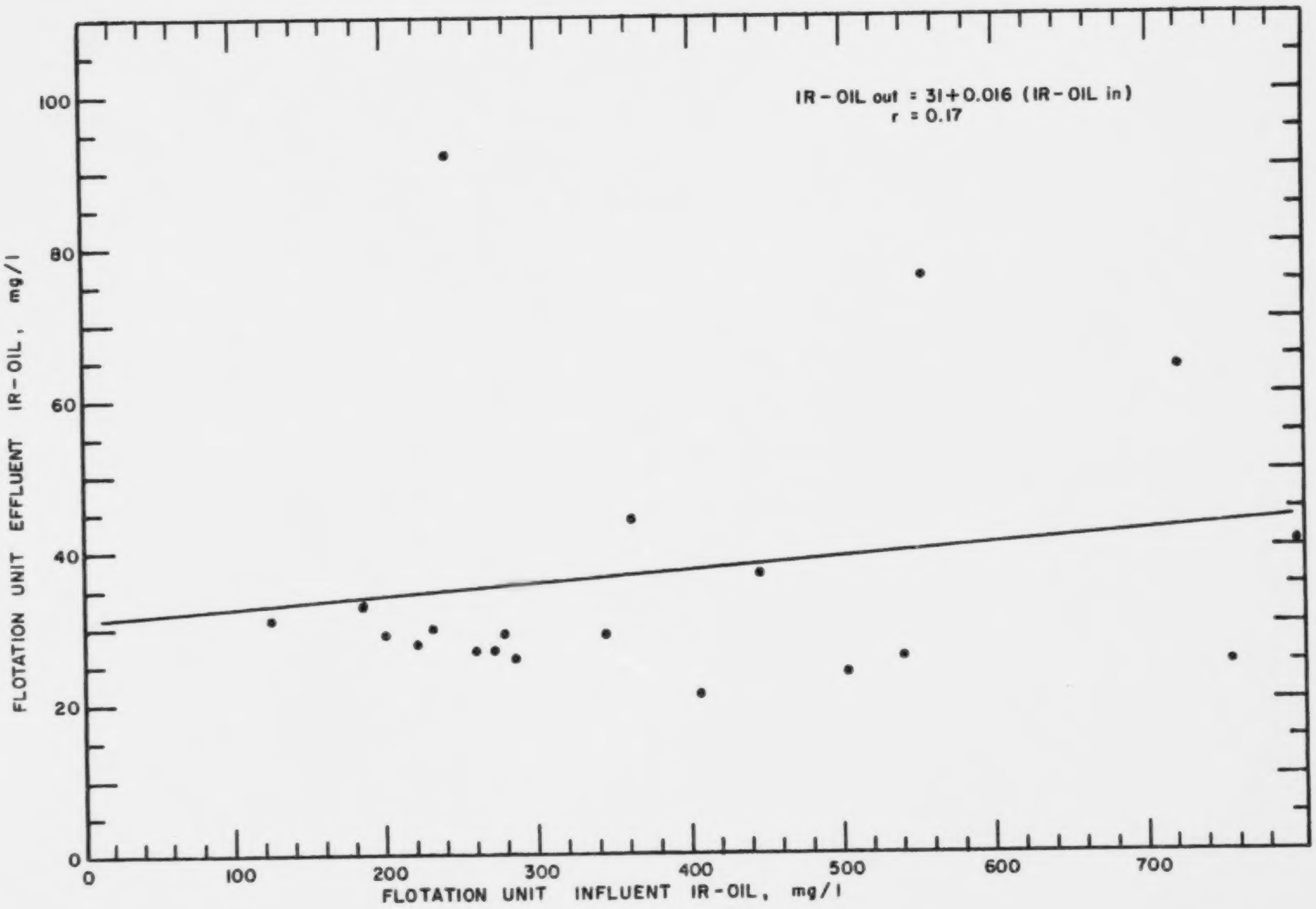


Figure 63. ST131 flotation unit in-out IR-oil regression.

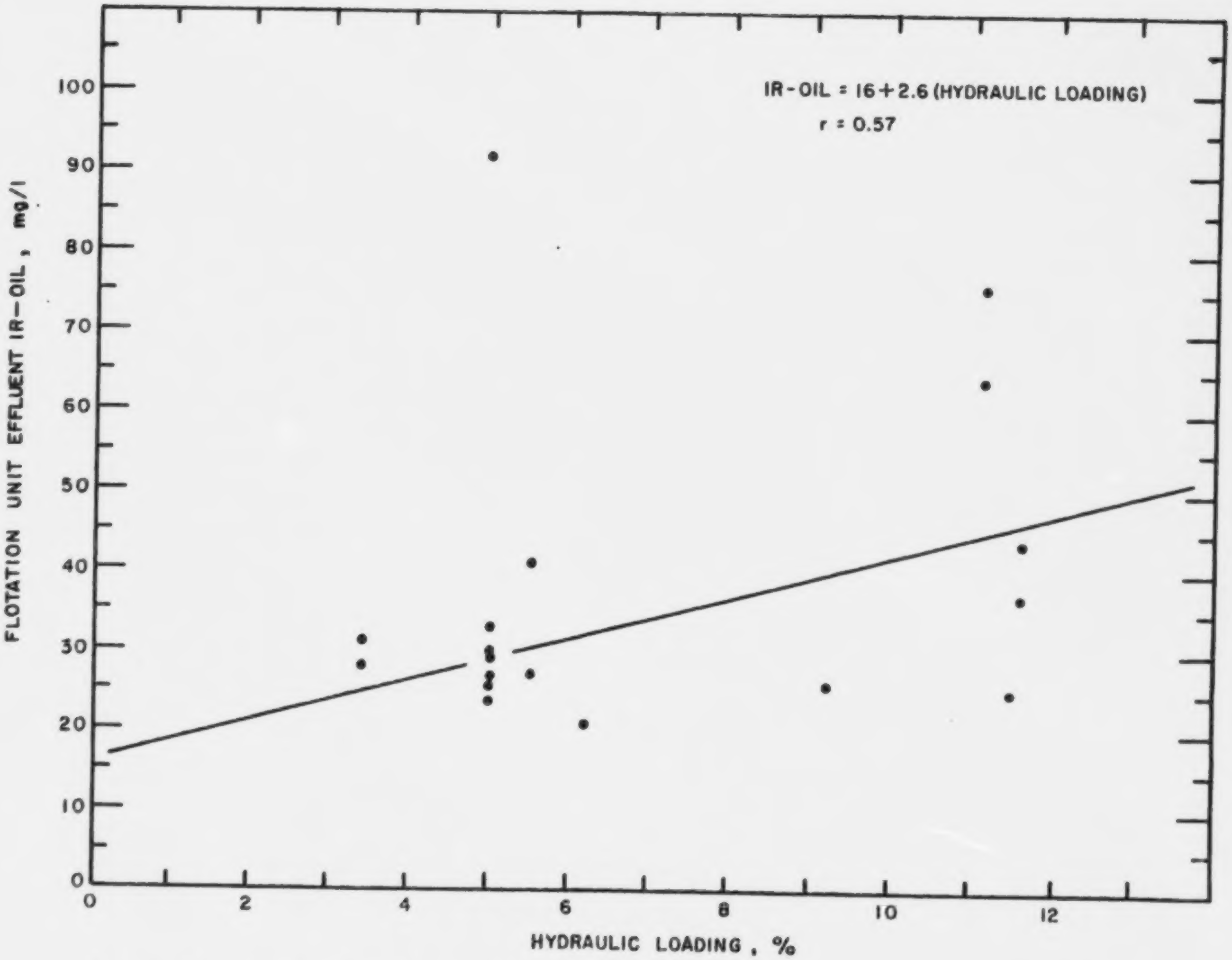


Figure 64. ST131 flotation unit hydraulic loading - infrared oil regression.

value for predicting performance at higher loadings.

Gravity Separator Performance

The sample point for the gravity separator effluent is the same as for the flotation unit influent (9--i).

Gravity separator influent (8--i) and effluent (9--i) oil content test data are presented in Table 94. The separator effluent IR-Oil content was in the range from 126 to 798 mg/l and the mean was 386 mg/l.

The results of three susceptibility to separation test runs are presented in Table 102. The mean IR-Oil content for the three runs of 330 mg/l after one hour of settling is moderately lower than the mean of 386 mg/l for twenty gravity separator effluent tests.

The largest oil drop detected by the particle size distribution test in the gravity separator effluent had a diameter of 49 μm.

Miscellaneous Brine Tests

All other brine test results for ST131 are listed in Tables 103, 104, 105 and 106. The results for the following tests were in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation for sample-to-sample variations in effluent oil content on ST131. These parameters will be discussed in a later section with respect to variations between platforms.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on ST131. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil results are listed in Tables 107 and 108. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one or two and are of primary significance for comparisons between platforms.

Two equilibration tests were run, each at a different oil/water ratio.

The limited number of tests run on crude oil provided only a limited characterization of the crude oil.

TABLE 102. ST131 SUSCEPTIBILITY TO SEPARATION TESTS ON GRAVITY SEPARATOR INFLUENT

	Settling time, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 1, 1300								
IR-Oil, mg/l	2,686	1,007	756	588	462	361	210	5,373
IR-Oil, %	-	(37)	(12)	(12)	(30)	(19)	(9)	-
IR-Oil W/Silica Gel, mg/l	1,931	-	546	-	-	-	126	-
Test Number 2 Day 2, 1300								
IR-Oil, mg/l	2,141	592	537	310	955	193	168	1,259
IR-Oil, %	-	(16)	(5)	(4)	(25)	(4)	(2)	-
IR-Oil W/Silica Gel, mg/l	1,763	-	525	-	-	-	126	-
Test Number 3 Day 7, 1300								
IR-Oil, mg/l	40,000	1,679	1,259	923	588	437	340	200,000
IR-Oil W/Silica Gel, mg/l	-	-	1,091	-	-	-	252	-
Average								
IR-Oil, mg/l	14,942	1,093	851	607	668	330	239	68,877
IR-Oil, %	-	26	8	8	28	12	6	-
IR-Oil W/Silica Gel, mg/l	1,847	-	721	-	-	-	168	-

( ) Percent of oil present in full sample that remains in bottom 1-liter of sample after settling.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 103. ST131 SUPPLEMENTARY BRINE TESTS

Sample time Day	 Hour	Temperature, °C 8--i	 9--i	 9--0	pH 9--0	Specific gravity[(1)] 9--0
01	08	24.0	22.0	23.0	6.2	1.128
02	08	26.5	25.5	25.0	6.1	1.135
03	08	26.0	24.0	19.0	6.2	1.139
04	08	21.5	22.0	22.5	6.7	1.139
05	08	26.0	25.5	25.0	6.6	1.140
06	08	22.0	22.5	22.5	6.6	1.113
07	08	21.5	21.0	21.0	6.1	1.125
08	08	22.0	22.0	22.0	6.2	1.125
09	08	21.0	21.5	23.0	6.3	1.126
10	08	18.0	22.0	23.0	6.2	1.122
Mean		22.9	22.8	22.6	6.3	1.129
Minimum		21.0	21.0	19.0	6.1	1.113
Maximum		26.5	25.5	25.0	6.7	1.140

Note: Sample point identification numbers (8--i, 9--i, 9--0) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 104. ST131 BRINE TESTS AT MINOR SAMPLING POINTS

Sample time Day	 Hour	IR-Oil, mg/l Sump (14--0)	Temperature, °C Sump (14--0)
08	08	2309	22.0
09	08	1553	23.0

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

TABLE 105. ST131 SULFATE REDUCING BACTERIA

Sample time	Bacteria per milliliter
Sump - Out (14--0)	100,000-1,000,000
Gravity Separator - In (8--i)	1,000,000
Flotation Unit - In (9--i)	10,000-100,000
Flotation Unit - Out (9--0)	10,000-100,000

Sample Day and Hour: 09 at 15

TABLE 106. ST131 IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	47,000
Potassium (K)	500
Calcium (Ca)	2,570
Magnesium (Mg)	1,140
Barium (Ba)	< 5
Chloride (Cl)	80,000
Sulfate (SO_4)	145
Alkalinity (as HCO_3)	183
Iron (Total)	18
Sulfide (as H_2S)	0.13
Total Dissolved Solids	
Summation	131,000
Gravimetric	138,000

Sample Day and Hour: 08 at 13

TABLE 107. ST131 CRUDE OIL MISCELLANEOUS TESTS(1)

Sample time Day	Sample time Hour	Temperature °C	Specific(2) gravity	Surface tension(3) dynes/cm
01	08	24.5	0.840	25
02	08	24.5	0.838	26
03	08	15.0	0.847	25
04	08	21.0	0.843	25
05	08	22.0	0.840	25
06	08	16.5	0.841	25
07	08	17.0	0.842	26
08	08	19.5	0.842	24
09	08	22.0	0.840	24
10	08	17.5	0.845	25
Mean		20.0	0.842	25
Minimum		15.0	0.838	24
Maximum		24.5	0.847	26

Sample time		Viscosity at 37.77°	
Day	Hour	Kinematic centistokes	Absolute centipoise
08	13	3.36	2.85

	Equilibration at 82°C Brine TDS = 131,000 mg/l	
Oil/Water Ratio	4/1	4.4/1
IR-Oil, mg/l	35	35
IR-Oil W/Silica Gel, mg/l	23	23
IR-Oil Filtered Brine, mg/l	17	18

---

(1) Samples taken from oil LACT unit.

(2) Specific gravity reported for temperature in table.

(3) Surface tension measured and reported at ambient temperatures from 10.0°C to 25.5°C.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTION HERE

TABLE 108. ST131 CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	480

Boiling range, °C	Percent recovered
Below - 200	61.7
200 - 250	22.6
250 - 300	8.8
300 - 350	1.6
350 - 400	0.3
400 - 450	0.1
450 - 500	0.0
Total	95.1

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

SECTION 11

PLATFORM BDCCF5

GENERAL

The ten-day testing survey was conducted on Platform BDCCF5 from April 1, 1980 through April 10, 1980.

A description of the production facilities, the test program, and data presentation and evaluation are presented in this section.

Three survey team members arrived at the platform on March 31 and the test equipment was set up the same day. Oil company personnel unloaded the equipment and provided living quarters, work space, sample taps, and the utilities needed to conduct the program.

The BDCCF5 Platform was located in shallow water. The production platform was unmanned, the only unmanned platform included in the survey. The quarters were about one kilometer away. Operating personnel visited the platform by boat at least once per day. The complete testing survey was carried out without interruption by weather, operating problems, or for any other reason.

FACILITIES AND OPERATIONS

Production From Wells

The number of wells producing was uniform from day to day. All oil wells produced continuously for the ten-day testing period. One well producing only gas, flowed from the sixth day to the tenth day.

Nineteen wells were producing. Five wells were flowing by formation pressure, and the other fourteen wells were gas lifted.

The estimated daily production for all wells was 180 m^3/d (1,131 bpd) of oil, 1,890 m^3/d (11,895 bpd) of water, and 145,600 std m^3/d (5,145 Mcfd) of gas. The calculated water cut was 91 percent.

Sixty-seven percent of the oil was gas lifted, and eighty-eight percent of the water was gas lifted.

Production Process System

The flow of oil and water through the system is shown in Figure 65.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-78)

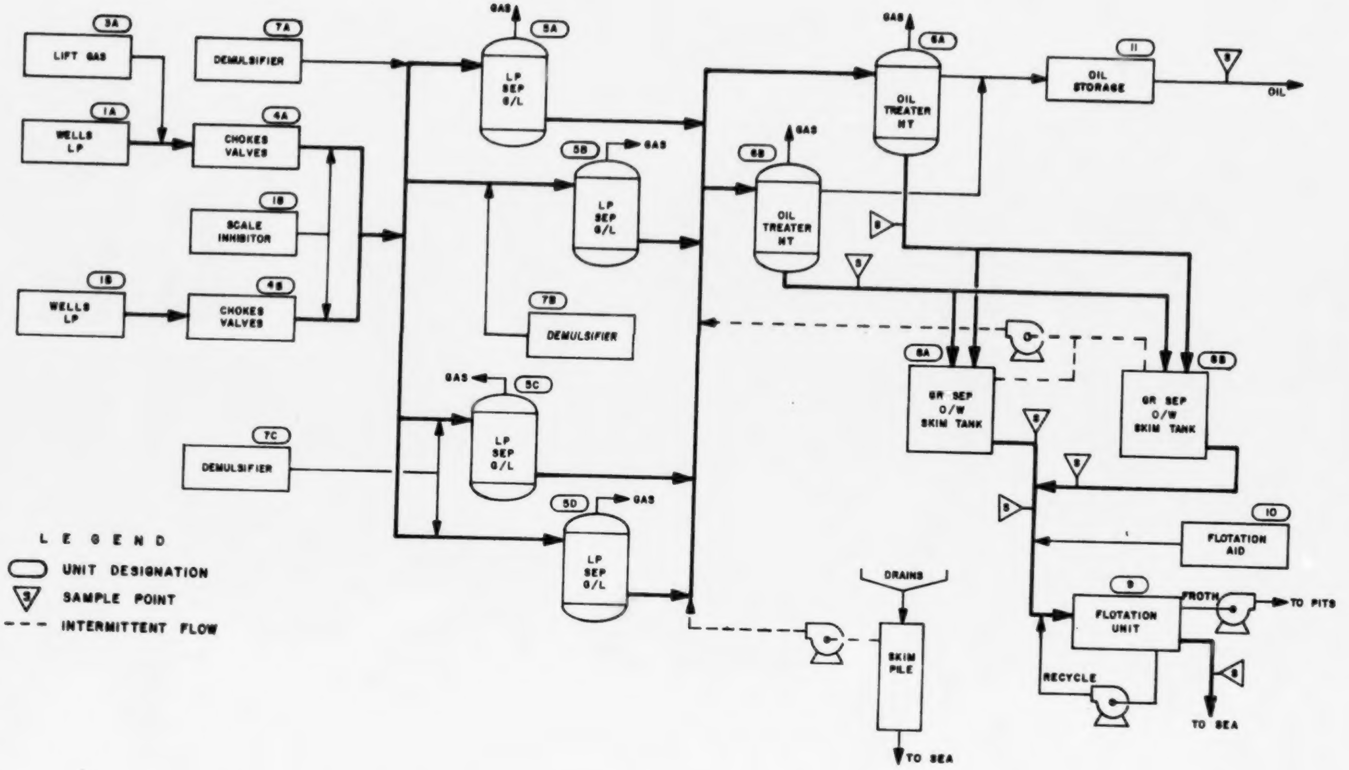

3A
LIFT GAS
1A
WELLS LP
1B
WELLS LP
7A
DEMULSIFIER
4A
CHOKES VALVES
1B
SCALE INHIBITOR
4B
CHOKES VALVES
7C
DEMULSIFIER
GAS
5A
LP SEP G/L
5B
LP SEP G/L
7B
DEMULSIFIER
5C
LP SEP G/L
5D
LP SEP G/L
6A
OIL TREATER HT
6B
OIL TREATER HT
11
OIL STORAGE
S
OIL
8A
GR SEP O/W SKIM TANK
8B
GR SEP O/W SKIM TANK
10
FLOTATION AID
9
FLOTATION UNIT
FROTH
TO PITS
RECYCLE
TO SEA
DRAINS
SKIM PILE
TO SEA
L E G E N D
UNIT DESIGNATION
S
SAMPLE POINT
INTERMITTENT FLOW

Figure 65. Flow diagram, production process system, BDCCF5.

Design and operating data on major vessels are presented in Table 109. The oil/water/gas flow is from the wells to four low-pressure gas-liquid separators operating in parallel.

A scale inhibitor, Tretolite WF-123, and a demulsifier, Tretolite BR-4050, are added to the produced fluids ahead of the low-pressure separators.

The oil/water flow from the four low-pressure separators is commingled and then split into two streams to flow through two oil treaters (heater treaters) in parallel. Oil is drawn from the oil treaters to storage tanks.

The primary water flow is from the oil treaters to two gravity oil/water separators operating in parallel. A combined stream flows from the gravity separators to a flotation unit and then to discharge.

A water treating chemical designed to aid in the separation of oil from water, Tretolite JW-8206, is added at the flotation unit inlet. The addition rate varied from 0 to 12.3 dm^3/d (3.2 gpd).

The skimmings from the flotation unit are pumped to a sludge pit.

Figure 66 is a flow schematic for the water handling system. The water flow rates in the figure are based on well test data. The skimmings flow rate is based on two measurements each day.

The two gravity separators on BDCCF5 are cylindrical skim tanks of almost identical configuration. They are 6.7 m (22 ft) in diameter by 4.9 m (16 ft) high. The operating water level is 4.2 m (13.75 ft). Water enters each skim tank through two 10 cm (4 in.) pipes projecting downward to about 0.3 m (1 ft) below the water surface near one side of the tank. The water flows from the tank through a 15 cm (6 in.) pipe about 1.2 m (4 ft) from the bottom on the opposite side of the tank. It appears that there could be significant short circuiting and turbulence of the flow in the gravity separators. There is not a generally accepted method of calculating the design capacity of these gravity separators.

The flotation unit (Monosep AG-20,000) is a proprietary unit with hydraulic gas dispersion. This type of unit was described in Section 7 and depicted in Figure 19. The unit on BDCCF5 has a design capacity of 3,180 m^3/d (20,000 bpd) of water. The average hydraulic loading was 1,890 m^3/d (11,890 bpd), or 59 percent of design.

SITE SPECIFIC TEST PROGRAM

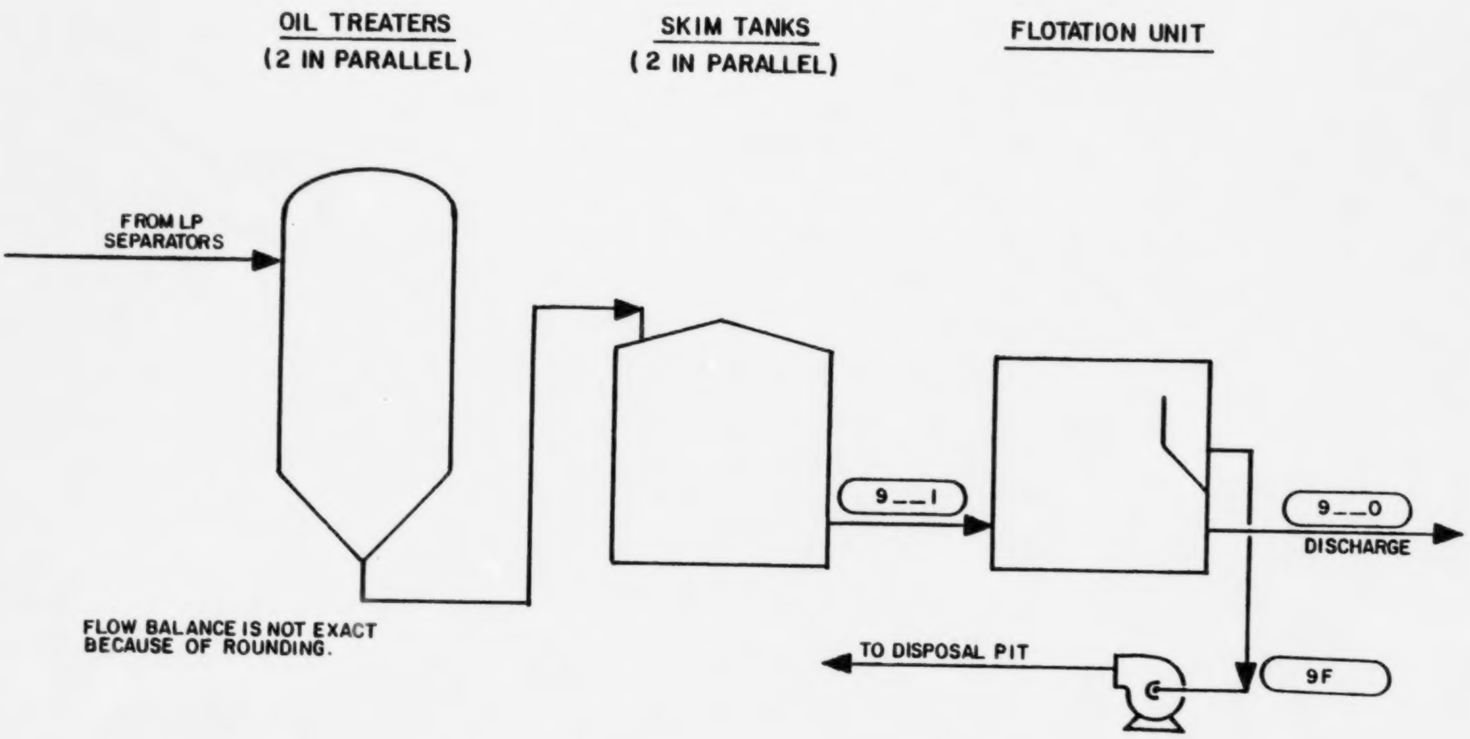
The planned test program for brine samples is presented in Table 110. The number of samples to be taken in ten days and the time the samples are to be taken each day are listed. The listed program was carried out with only minor variations as will be observed later.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

TABLE 109. BDCCF5 VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 11-1			
	5A,5B,5C & 5D Low pressure 2-phase separators	6A & 6B[1] Low pressure 3-phase oil treaters	8A & 8B[1] Gravity separators skim tanks	9 Flotation unit hydraulic dispersed gas
Trade Name or Vessel Type	Vertical Cylinder	Vertical Cylinder Cone Bottom	Vertical Cylinder	Monosep Model AG-20,000
Design Parameters				
Dimensions, m, (ft)				
Diameter, O.D.	-	3.0(10)	6.7(22)	-
Length, S.S.	-	-	-	-
Length	-	-	-	5.0(16.5)[2]
Width	-	-	-	3.7(12)[2]
Height	-	10.7(35)	4.9(16)	2.3(7.5)[2]
Separation Surface Area, m^2,(ft^2)				
Total	-	7.2(78)	35(380)	10.7(115)
Per Cell	-	7.2(78)	35(380)	10.7(115)
Volume, m^3,(bbl)				
Total	-	-	-	-
Oil Phase	-	-	-	-
Water Phase	-	29.6(186)	148(930)	24.5(154)[2]
Number of Cells	-	-	-	1
Flow Rate, m^3/day,(bpd)[3]	-	-	-	3,180(20,000)
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)[3]	-	-	-	297(174)
Recycle Rate, Percent of Flow	-	-	-	400
Retention Time, min.[3]	-	-	-	11
Average Operating Parameters				
Temperature, $^oC(^oF)$	-	41(106)	41(106)	41(106)
Pressure, kPag (psig)	517(75)	124(18)	0	0
Flow Rate, m^3/d, (bpd)	-	945(5,945)	945(5,945)	1,890(11,890)
Flow Rate, Percent of Design	-	-	-	59
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)[3]	-	131(76)	27(16)	177(103)
Recycle Rate, Percent of Flow[3]	-	-	-	670
Froth Flow, Percent of Flow	-	-	-	<1

(1) Data for each of two tanks.
(2) For water in separation tank only.
(3) Based on effluent flow. Overflow rate is surface area divided by flow rate.


OIL TREATERS
(2 IN PARALLEL)
SKIM TANKS
(2 IN PARALLEL)
FLOTATION UNIT
FROM LP SEPARATORS
FLOW BALANCE IS NOT EXACT BECAUSE OF ROUNDING.
9__I
9__O
DISCHARGE
TO DISPOSAL PIT
9F

WATER FLOW	9F	9__I	9__O
m^3/d	5	1890	1890
bpd	30	11,890	11,890

Figure 66. BDCCF5 water handling system flow schematic.

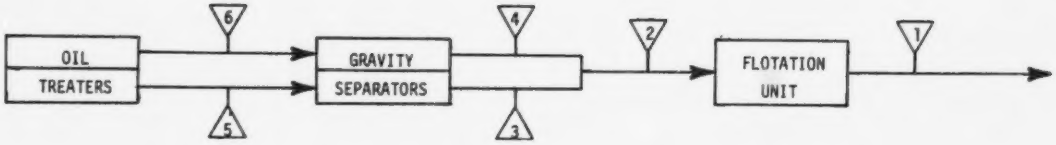


TABLE 110. BDCCF5 TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS											
	1 9--0		2 9--1		3 8B-0		4 8A-0		5 6B-0		6 6A-0	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests												
Infrared Oil	20	8,13	20	8,13	10	8	10	8	10	8	10	8
Temperature	10	8	10	8	10	8	10	8	10	8	10	8
pH	10	8	-	-	-	-	-	-	-	-	-	-
Water Specific Gravity(2)	10	8	-	-	-	-	-	-	-	-	-	-
Water Surface Tension	10	8	10	8	-	-	-	-	-	-	-	-
IR-Oil W/Silica Gel	20	8,13	10	8	-	-	-	-	-	-	-	-
IR-Oil Filtered Brine	20	8,13	10	8	-	-	-	-	-	-	-	-
Susceptibility to Separation(3)	-	-	3	13	-	-	-	-	-	-	-	-
Laboratory Tests												
Gravimetric Oil	40	8,10,13,15	10	8	-	-	-	-	-	-	-	-
Suspended Solids	10	8	10	8	-	-	-	-	-	-	-	-
Ionic Analysis	1	(1)	-	-	-	-	-	-	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.											
Particle Size Distribution(4)	3	13	-	-	3	13	3	13	-	-	-	-

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/silica gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/silica gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operations are reported in this subsection.

Flow Monitoring

Continuous flow monitoring was not accomplished on BDCCF5. The rented Doppler meter was tried at several points in the system, but positive readings were not obtained. The apparent problem was that the flowing streams did not contain sufficient particulate matter, or sufficient turbulence to provide input to the monitor.

It is believed that variations in flow during the program were minor. All oil wells produced continuously, and there were not any significant recycle flows.

Well Test Data

The well test data provided by the operator are presented in Table 111.

Pressure Drops Through System

Flowing tubing pressures were obtained from well test records. The pressure of major vessels was recorded twice per day. Pressure drops in the system are reported in Table 112. The data were recorded to permit examining the theory that turbulence occurring with the pressure drops at chokes and valves may form small particle dispersions that are difficult to remove in the separation equipment.

Chemical Addition

Three chemicals were added continuously by small metering pumps.

A scale inhibitor, Tretolite WF-123, was added to the manifold ahead of the low-pressure separators. The addition rate was uniform at just under 0.95 dm^3/d (0.25 gpd). A demulsifier, Tretolite BR-4050, was added to the same manifold at four different points. The addition of the demulsifier was also uniform at a total rate of 5.3 dm^3/d (1.4 gpd).

A flotation aid, Tretolite JW-8206, was added to the inlet of the flotation unit. The addition rate was not uniform. An addition rate for each major sampling time is presented in Table 113.

Observations and Operator Reports

Any occurrences observed by the survey team or reported by the operators were recorded if they had potential significance with respect to effluent oil content.

Production rates were very uniform for the ten-day period. There were not any changes that affected liquid flow rates. Three wells producing

TABLE 111. BDCCF5 WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig		Choke size 1/64 in.	API gravity	Days of production
							SIBHP	FTP			
Flowing to Low Pressure Separator											
B-20	-	1,524	584	0	0	0	-	440	28	-	All
B-47	-	1,520	2,043	0	0	0	-	445	48	-	All
B-80	-	8,165	110	120	1,112	0	-	150	open	28.9	All
B-97	-	8,780	150	251	307	0	-	580	16	33.5	All
B111	-	1,530	1,640	0	0	0	-	475	48	-	6-10
Total (Average)		-	4,527	371	1,419	-	-	-	-	(31.2)	
Gas Lift to Low Pressure Separator											
B-27	-	8,155	5	10	1,005	489	-	130	open	28.6	All
B-30	-	8,275	18	26	850	478	-	260	open	35.7	All
B-32	-	8,395	228	9	3	7	-	100	open	36.5	All
B-72D	-	8,100	48	102	918	147	-	100	open	28.2	All
B-73	-	8,020	10	20	1,730	602	-	200	open	28.4	All
B-76	-	8,140	23	41	1,867	485	-	210	open	29.5	All
B-78	-	8,015	80	153	1,664	438	-	225	open	30.0	All
B-86	-	8,250	71	150	0	399	-	120	open	28.5	All
B-91	-	8,400	73	132	1,332	422	-	180	open	29.5	All
B-99	-	4,430	4	18	54	473	-	180	open	28.3	All
B109	-	4,400	6	16	24	232	-	120	open	29.5	All
B119	-	7,750	15	26	106	428	-	200	open	34.9	All
B121	-	5,760	15	25	815	371	-	290	open	35.7	All
B122	-	8,240	22	32	8	421	-	125	open	36.8	All
Total (Average)	-	-	618	760	10,476	5,392	-	-	-	(31.4)	
Combined Total (Average)		-	5,145	1,131	11,895	5,392	-	-	-	(31.4)	

TYPING GUIDE SHEET

TABLE 112. BDCCF5 PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Low Pressure Wells, Flowing Tubing Pressure	690-4,000 (100-580)	chokes, pipes	110-3,520 (16-510)
Low Pressure Separators	480-580 (70-84)	valves, pipes	356-456 (52-66)
Oil Treaters	124 (18)	valves, pipes	124 (18)
Skim Tanks	0		

primary gas were off for a short time after samples were taken on the second day. There were not any operational problems that disrupted the program.

On Day 2, just after the 0800 samples were taken, a survey team member unintentionally left the valve from the flotation chemical storage tank off after a flow rate check. When turned on later that day, the pump did not work. Flotation chemical feed was restarted on Day 3 at 0940 after a check valve was replaced.

On Day 10 at 1000 9.5 dm^3 (2.5 gallons) of biocide was added to the 8A skim tank. The biocide was Tretolite X-CIDE 102. The operators expect foaming in the flotation unit when biocide is added. Minor foaming did occur in the flotation unit. Any effect on flotation influent and effluent oil content should have been detected in the 1300 sample. No effect on oil content was measured.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables, summary tables and graphs for BDCCF5 are interspersed in the text.

Effluent Oil Content

Table 114 presents a listing of oil content test results for the major sampling points. Figure 67 presents a plot of GR-Oil in and out of the flotation unit versus time. Figure 68 presents the same plot for IR-Oil content.

EPA-287 (Cin.)
(4-76)

TABLE 113. BDCCF5 FLOTATION CHEMICAL ADDITION

Day	Hour	Addition rate[(1)] dm³/d	Addition rate[(1)] ppmv
01	08	5.2	3
	13	5.2	3
02	08	5.2	3
	13	0(2)	0(2)
03	08	0(2)	0(2)
	13	6.6	3
04	08	12.3	7
	13	11.4	6
05	08	7.6	4
	13	7.6	4
06	08	6.6	3
	13	11.4	6
07	08	11.4	6
	13	11.4	6
08	08	11.4	6
	13	11.4	6
09	08	11.4	6
	13	11.4	6
10	08	10.4	6
	13	10.4	6
Mean		9.4	5

(1) The addition rate for Tretolite JW-8206 based on average water flow through the flotation unit.
(2) Not included in mean.

The tabulated data and time-indexed plots show that the flotation influent oil content is exceptionally uniform from sample to sample. The flotation effluent oil content is also quite uniform except for Day 2 and Day 3. The high oil content values on these days occurred when the survey team unintentionally shut off the flotation chemical feed. The importance of flotation chemical for effective oil flotation is demonstrated for BDCCF5.

The ranges of test results, not including those when chemical was not added, are as follows:

Flotation Effluent GR-Oil - 14 to 45 mg/l,
Flotation Effluent IR-Oil - 25 to 52 mg/l,
Flotation Influent GR-Oil - 70 to 101 mg/l,
Flotation Influent IR-Oil - 91 to 152 mg/l.

Flotation unit effluent oil content histograms for the two test methods are presented in Figure 69 and Figure 70. Figure 71 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one

TABLE 114. BDCCF5 MAJOR BRINE TESTS

Sample time		Flotation unit influent (9--i)						Flotation unit effluent (9--0)							
				IR-Oil w/silica gel		Filtered brine				IR-Oil w/silica gel		Filtered brine		Flow rate	
Day	Hour	GR-Oil	IR-Oil	Dispersed	Soluble	IR-Oil	Surface tension	GR-Oil	IR-Oil	Dispersed	Soluble	IR-Oil	Surface tension	Out	Skimmings
		mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	70	134	69	65	9	62	33	49	38	11	8	55	1,890	2
01	10	-	-	-	-	-	-	38	-	-	-	-	-	1,890	2
01	13	-	108	-	-	-	-	39	50	38	12	9	-	1,890	11
01	15	-	-	-	-	-	-	45	-	-	-	-	-	1,890	11
02	08	73	100	61	39	9	65	33	52	43	9	10	60	1,890	4
02	10	-	-	-	-	-	-	36	-	-	-	-	-	1,890	4
02	13	-	130	-	-	-	-	77(C)	126(C)	65(C)	61(C)	11(C)	-	1,890	7
02	15	-	-	-	-	-	-	81(C)	-	-	-	-	-	1,890	7
03	08	79	104	56	48	9	61	49(C)	64(C)	52(C)	12(C)	8(C)	58(C)	1,890	7
03	10	-	-	-	-	-	-	26(C)	-	-	-	-	-	1,890	7
03	13	-	152	-	-	-	-	88(C)	139(C)	104(C)	35(C)	13(C)	-	1,890	11
03	15	-	-	-	-	-	-	84(C)	-	-	-	-	-	1,890	11
04	08	73	121	13	108	7	67	21	30	18	12	6	62	1,890	3
04	10	-	-	-	-	-	-	14	-	-	-	-	-	1,890	3
04	13	-	91	-	-	-	-	18	25	13	12	8	-	1,890	3
04	15	-	-	-	-	-	-	23	-	-	-	-	-	1,890	3
05	08	101	108	69	39	10	62	24	33	25	8	10	64	1,890	4
05	10	-	-	-	-	-	-	22	-	-	-	-	-	1,890	4
05	13	-	100	-	-	-	-	26	32	25	7	10	-	1,890	3
05	15	-	-	-	-	-	-	32	-	-	-	-	-	1,890	3
06	08	91	113	74	39	9	64	32	47	38	9	8	59	1,890	4
06	10	-	-	-	-	-	-	24	-	-	-	-	-	1,890	4
06	13	-	108	-	-	-	-	31	40	31	9	8	-	1,890	3
06	15	-	-	-	-	-	-	25	-	-	-	-	-	1,890	3
07	08	75	95	56	39	9	64	14	29	20	9	9	63	1,890	3
07	10	-	-	-	-	-	-	19	-	-	-	-	-	1,890	3
07	13	-	104	-	-	-	-	22	29	22	7	7	-	1,890	5
07	15	-	-	-	-	-	-	22	-	-	-	-	-	1,890	5
08	08	80	117	69	48	11	67	21	33	23	10	8	60	1,890	4
08	10	-	-	-	-	-	-	23	-	-	-	-	-	1,890	4
08	13	-	113	-	-	-	-	25	33	25	8	8	-	1,890	4
08	15	-	-	-	-	-	-	25	-	-	-	-	-	1,890	4
09	08	81	130	39	91	9	63	21	33	19	14	9	64	1,890	4
09	10	-	-	-	-	-	-	23	-	-	-	-	-	1,890	4
09	13	-	113	-	-	-	-	24	32	19	13	9	-	1,890	3
09	15	-	-	-	-	-	-	27	-	-	-	-	-	1,890	3
10	08	80	113	26	87	11	64	25	35	21	14	8	63	1,890	4
10	10	-	-	-	-	-	-	5(A)	-	-	-	-	-	1,890	4
10	13	-	100	-	-	-	-	25	33	21	12	9	-	1,890	5
10	15	-	-	-	-	-	-	28	-	-	-	-	-	1,890	5
Minimum		70	91	13	39	7	61	14	25	13	7	6	55	-	2
Maximum		101	152	74	108	11	67	45	52	43	14	10	64	-	11

(A) Not included in statistical analysis. Appears inconsistent with other IR-Oil, GR-Oil, and IR-Oil W/Silica Gel Tests.
(C) Not included in statistical analysis. The survey team inadvertently shut off the feed of flotation chemical to the system.

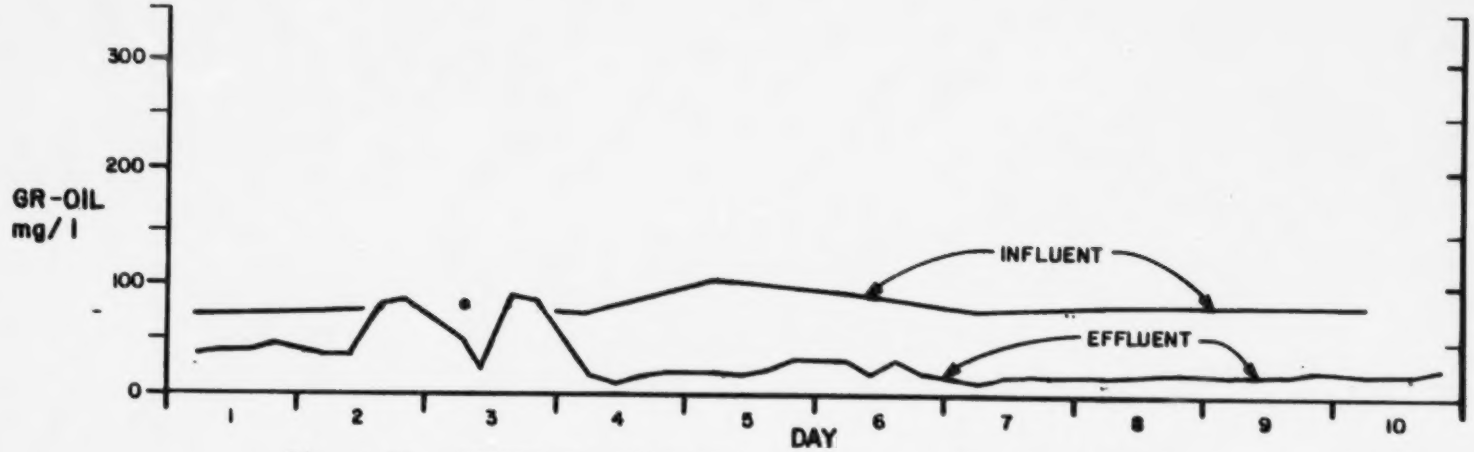


Figure 67. BDCCF5 flotation unit performance, GR-oil vs time.

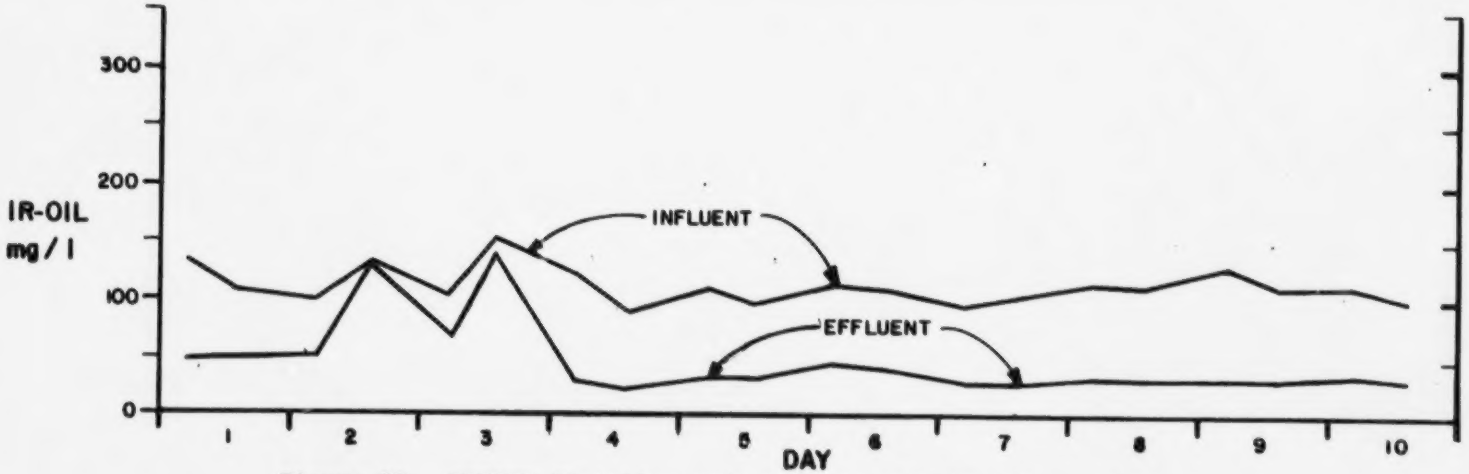


Figure 68. BDCCF5 flotation unit performance, IR-oil vs time.

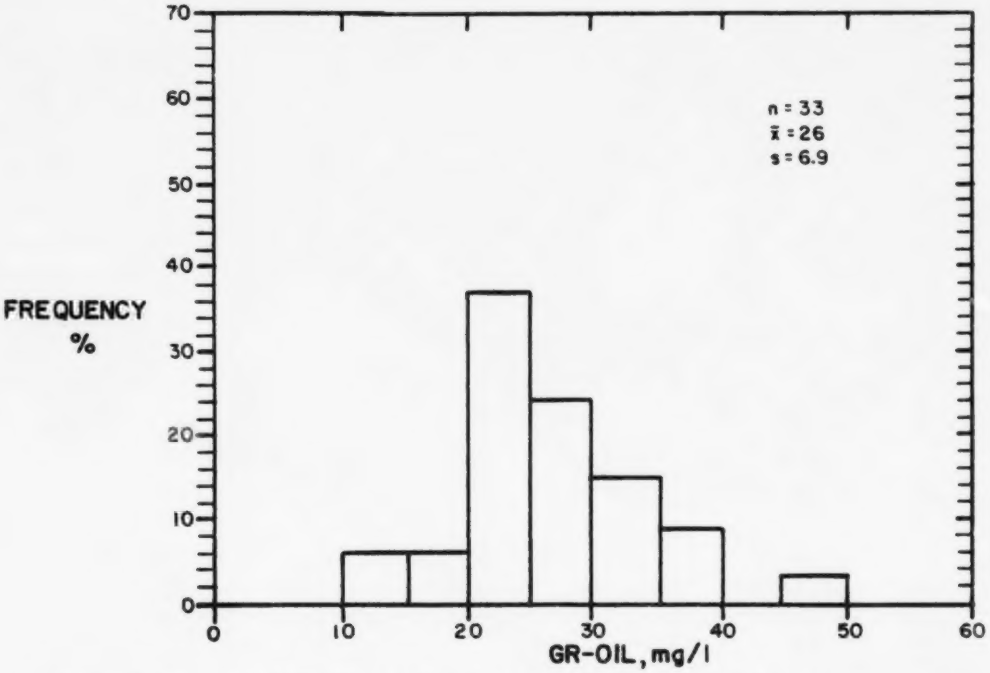


Figure 69. BDCCF5 flotation unit effluent, GR-oil histogram.

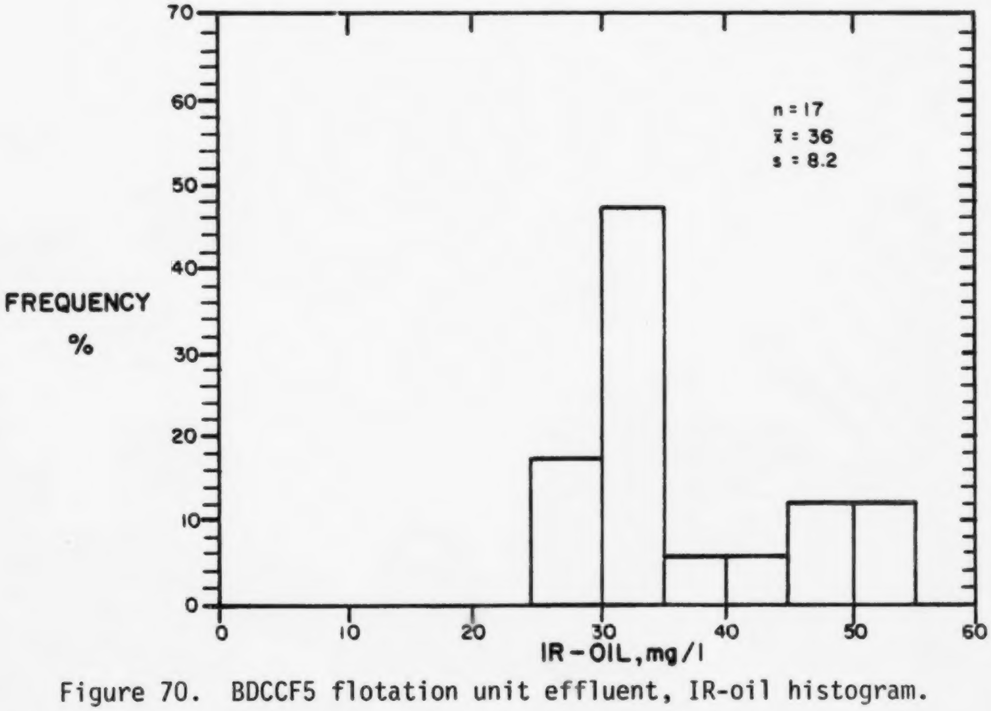


Figure 70. BDCCF5 flotation unit effluent, IR-oil histogram.

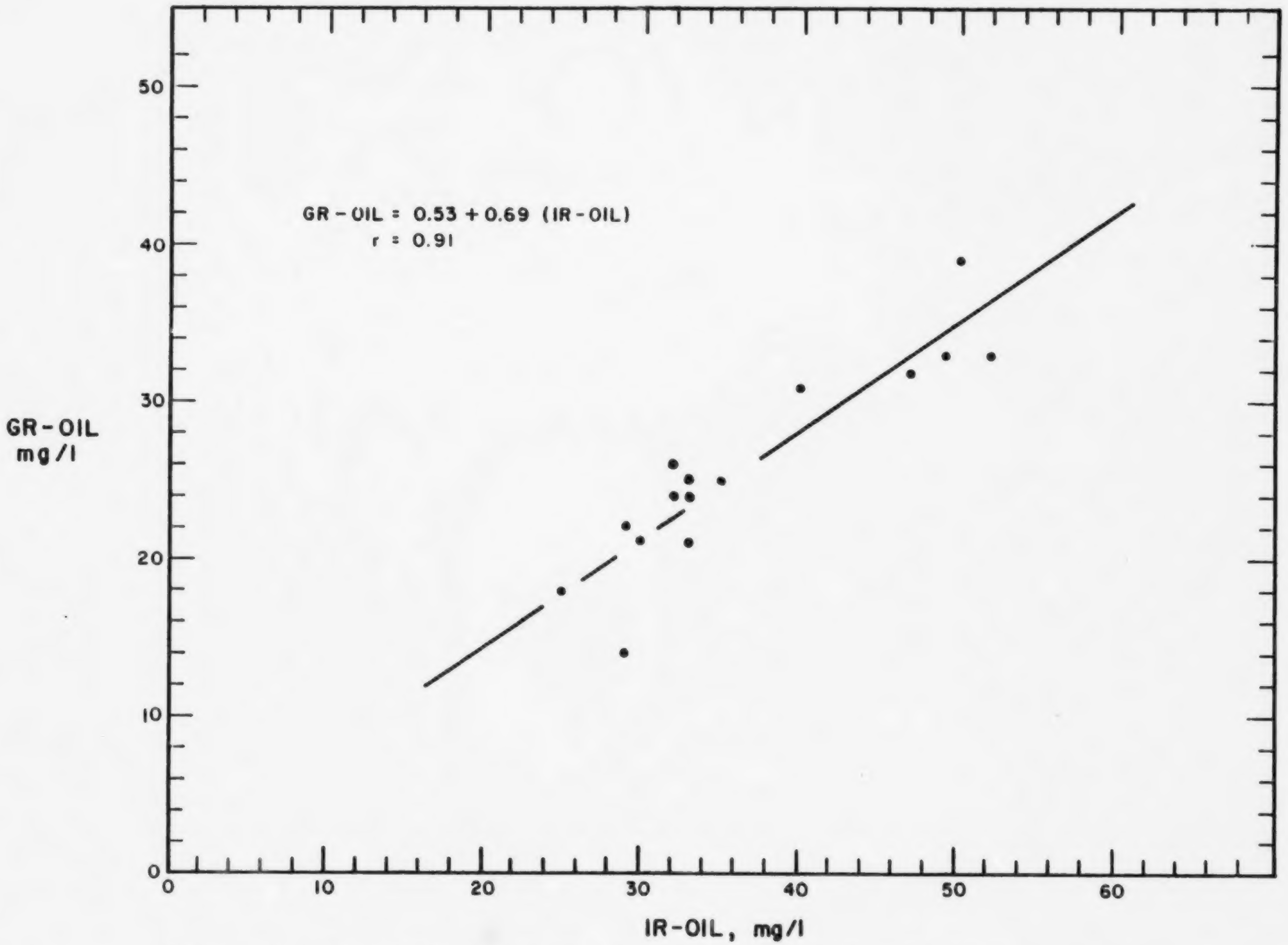


Figure 71. BDCCF5 flotation unit effluent, infrared-gravimetric regression.

minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Table 115 presents a summary comparison of test results by the two methods.

TABLE 115. BDCCF5 FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	33	17
Mean, $(\bar{x})$, mg/l	26	36
Minimum, mg/l	14	25
Maximum, mg/l	45	52
Standard Deviation, (s), mg/l	6.9	8.2
	Paired tests	
Number, (n)	17	
Mean of Differences, $(\bar{\Delta})$, mg/l	10.6	
Standard Deviation, (s_Δ), mg/l	3.7	

The mean oil content of the flotation effluent is 10 mg/l higher by the IR-Oil test method than by the GR-Oil test. The regression plot and the correlation coefficient of 0.91 shown in Figure 71 illustrate a significant relationship between results by the two test methods. This significant relationship is confirmed by the standard deviation of only 3.7 mg/l for differences in paired tests as presented in Table 115.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 114. A summary of these test results is presented in Table 116.

TABLE 116. BDCCF5 SUSPENDED SOLIDS SUMMARY

	Flotation effluent		
Analysis or test	Range mg/l	Mean mg/l	Proportion of total, percent
IR-Oil	25-52	36	100
Dispersed Oil	13-43	26	72
Soluble Oil	7-14	10	28

Note: Table includes only IR-Oil tests when an IR-Oil w/Silica Gel test was run.

On average, 28 percent of the oil in the effluent was soluble oil and 72 percent was dispersed oil.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 72. There is a significant correlation between dispersed oil and total oil as measured by both standard tests. Extrapolations of the linear regression lines to zero dispersed oil indicate a residual IR-Oil of 12 mg/l and a residual GR-Oil of 9 mg/l after all dispersed oil is removed.

The mean soluble oil content of the flotation influent was 60 mg/l, significantly higher than the mean of 10 mg/l of the flotation unit effluent.

Surface Tension

All surface tension test results are listed in Table 114. The mean surface tension of the flotation influent is 64 dynes/cm and of the flotation effluent is 61 dynes/cm. The range for flotation effluent test results was from 55 dynes to 64 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 219 - 2.94\ (\text{Surface Tension})$$
$$r = -0.73$$

The test results on Day 2 when the system was upset were included in calculating the regression equation. A decrease in oil content is indicated for an increase in surface tension.

Suspended Solids

Suspended solids test data are presented in Table 117 for major sampling points.

A suspended solids summary for BDCCF5 is presented in Table 118.

Most of the solids in the flotation influent and effluent were Freon soluble. The concentrations of Freon insoluble solids were low, and no fixed solids were present.

Figure 73 presents time-indexed plots of Freon insoluble suspended solids in the flotation unit influent and effluent, and of flotation effluent dispersed oil. All samples were taken at the same time, 0800 each day. The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when suspended solids are higher in the flotation unit influent or effluent. As discussed in Section 18, the suspended solids test method may not have sufficient precision to provide meaningful results at the solids concentrations in the BDCCF5 brine.

Filtered Brine

The filtered brine IR-Oil test results on BDCCF5 flotation influent were in the range from 7 to 11 mg/l. Those on the flotation effluent were in the

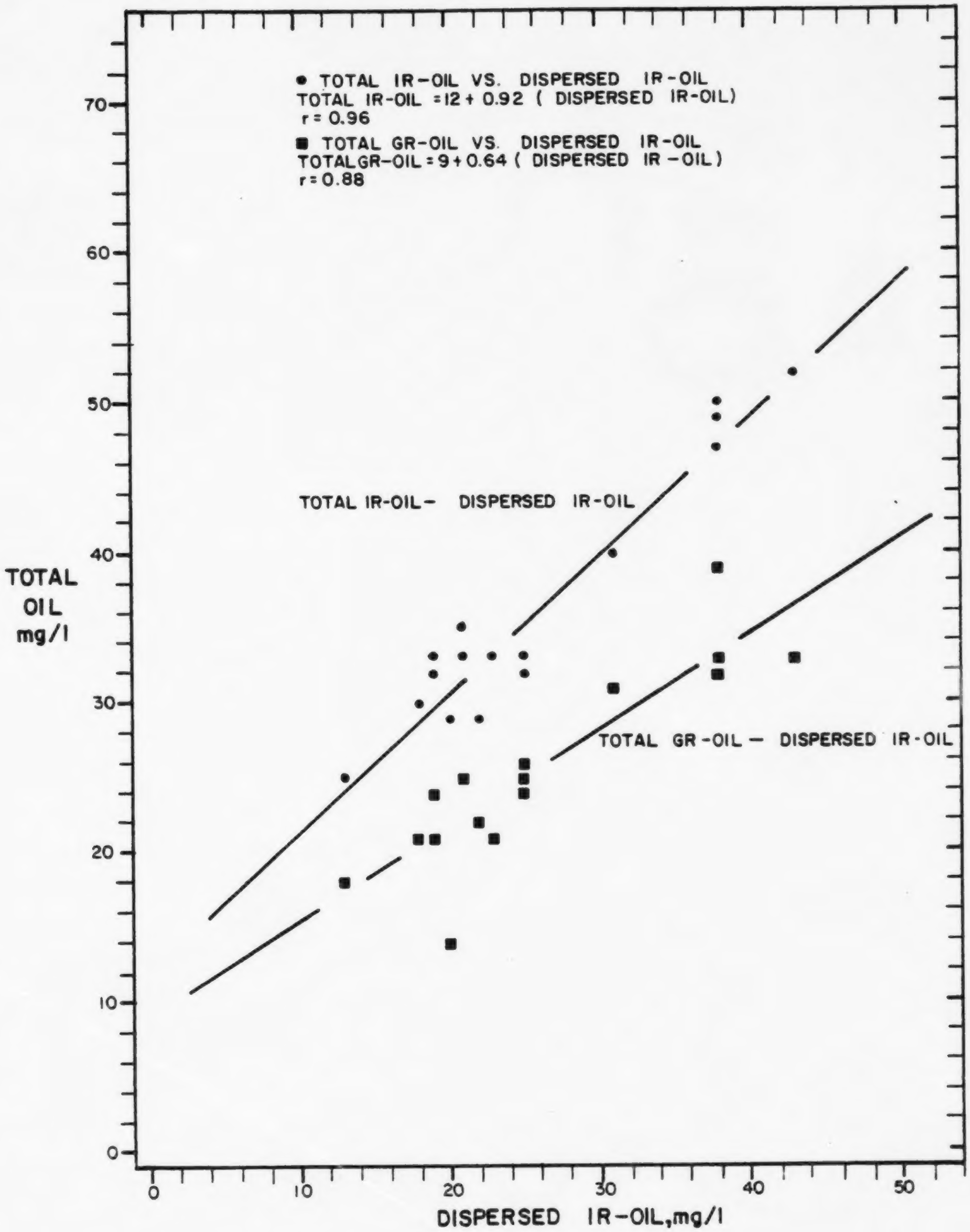


Figure 72. BDCCF5 flotation unit effluent, total oil - dispersed oil regression.

TABLE 117. BDCCF5 SUSPENDED SOLIDS TESTS

Sample time		Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	60	50	11	11	0	57	32	25	24	1
02	08	49	43	6	6	0	40	26	15	15	0
03	08	61	55	5	4	2	38	26	13	9	4
04	08	40	36	4	4	0	35	16	20	20	0
05	08	43	40	3	3	0	32	17	14	14	0
06	08	47	43	5	5	0	42	26	15	15	1
07	08	34	32	2	2	0	28	16	12	12	0
08	08	37	32	4	4	0	20	13	7	7	0
09	08	43	39	5	4	0	25	16	10	9	1
10	08	38	33	5	5	0	33	20	13	13	0
Minimum		34	32	2	2	0	20	13	7	7	0
Maximum		61	55	11	11	2	57	32	25	24	4

TABLE 118. BDCCF5 SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l	
	9--i	9--0
Total	45	35
Freon Soluble	40	21
Freon Insoluble	5	14
Acid Soluble	5	14
Fixed	0	0

range from 6 to 10 mg/l. These test results exhibit exceptional consistency. The concentration of oil that was not removed by filtration was essentially the same in the flotation influent and effluent brines.

Flotation Unit Performance

Figure 74 is a regression plot of IR-Oil in and out of the flotation unit. The effluent oil content increases slightly as the influent increases. However, the correlation coefficient of 0.27 is low. Only minor significance can be attached to the relationship of flotation influent and effluent oil content.

Flow was not monitored on BDCCF5. Therefore, it is not possible to examine the oil content test results for sample-to-sample variations with hydraulic loading.

Gravity Separator Performance

Two gravity separators, 8A and 8B, were operating in parallel. The brine

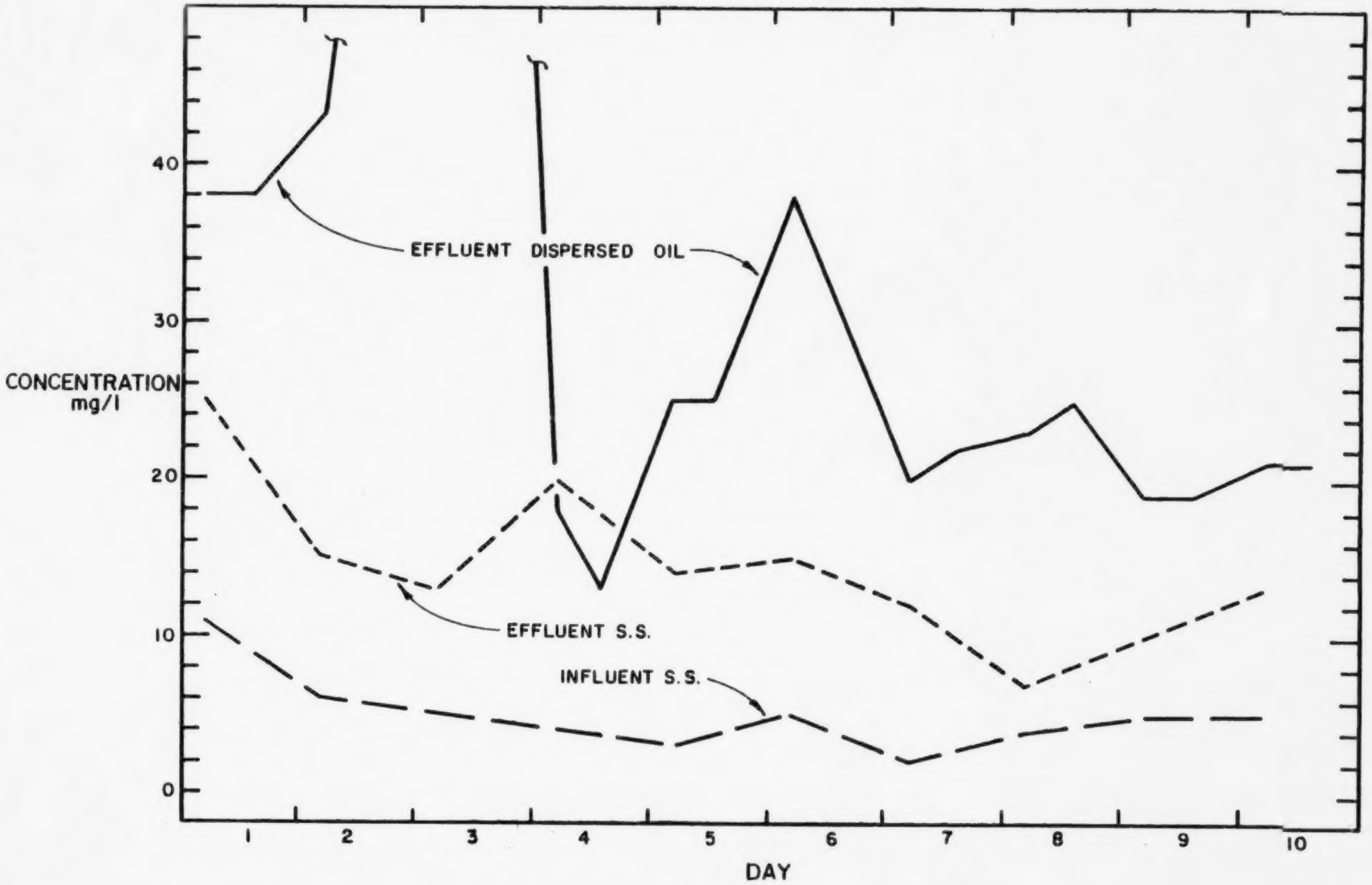


Figure 73. BDCCF5 flotation unit Freon insoluble suspended solids.

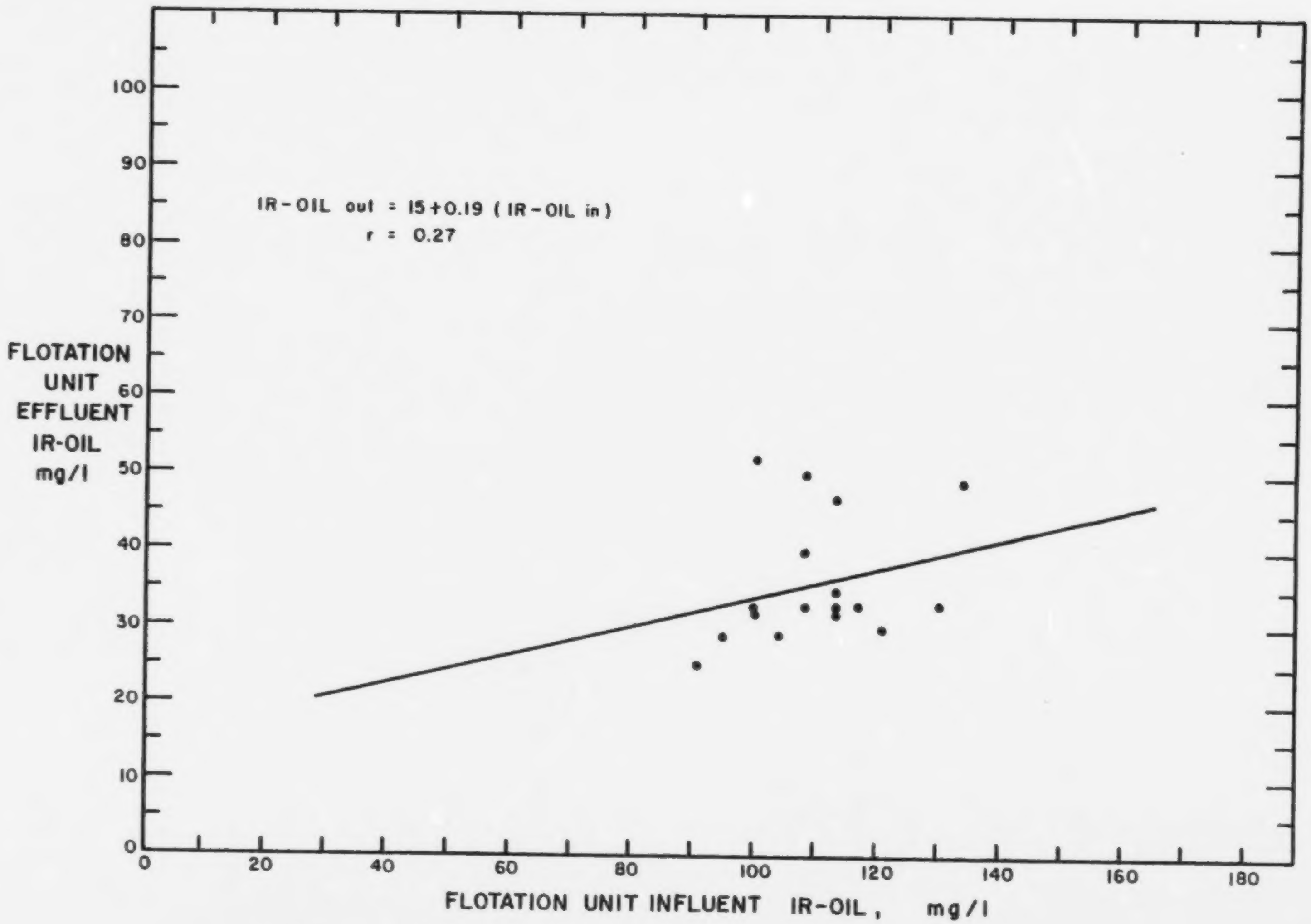


Figure 74. BDCCF5 flotation unit in-out IR-oil regression.

oil contents in and out of the separators are listed in Table 119. The 6A-0 and 6B-0 samples were taken at the outlets of the two oil treaters ahead of the gravity separators. The brine effluents from both oil treaters flowed to both gravity separators, so that it was not possible to know the exact volume or oil content of the gravity separator influents. The IR-Oil content range for the influents was 208 to 438 mg/l.

TABLE 119. BDCCF5 BRINE TESTS AT MINOR SAMPLING POINTS

Sample time		IR-Oil, mg/l				Temperature, °C			
Day	Hour	6A-0	6B-0	8A-0	8B-0	6A-0	6B-0	8A-0	8B-0
01	08	208	429	781	91	38.0	42.5	41.5	43.0
02	08	226	234	191	82	38.0	44.0	40.0	41.0
03	08	334	364	200	91	38.0	44.0	40.5	42.0
04	08	234	377	173	87	38.0	42.5	41.0	41.5
05	08	243	278	147	113	35.5	42.5	39.5	40.0
06	08	234	299	147	113	38.5	43.5	40.5	42.0
07	08	239	330	152	68	39.0	45.5	41.0	41.5
08	08	265	230	195	91	39.5	45.0	42.0	42.0
09	10	234	438	173	100	38.0	44.0	40.5	41.0
10	10	230	434	147	87	39.0	44.5	41.0	41.5
Mean		245	341	231	92	38.2	43.8	40.8	41.6
Minimum		208	230	147	68	35.5	42.5	39.5	40.0
Maximum		334	438	781	113	39.5	45.5	42.0	43.0

Note: 6A-0 is the 6A heater treater effluent.
6B-0 is the 6B heater treater effluent.
8A-0 is the 8A gravity separator effluent.
8B-0 is the 8B gravity separator effluent.

The IR-Oil contents of the effluents of the gravity separators are listed under 8A-0 and 8B-0 in Table 119.

The oil contents of the combine gravity separator effluents are listed under 9--i in Table 114. The 9--i test results also represent the flotation unit influent.

The range of IR-Oil test results representative of gravity separator effluents are as follows:

Separator, 8A-0 - 147 to 781 mg/l
Separator, 8B-0 - 68 to 113 mg/l
Combined, 9--i - 91 to 152 mg/l

The oil contents at 8B-0 and 9--i were quite consistent. The effluent

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

oil content of separator 8A was both higher and less consistent than that of separator 8B. The reason for the difference was not determined.

The results of the susceptibility to separation tests for sampling point 9--i are presented in Table 120. These test results show that additional oil can be removed by static settling even though the oil contents of the unsettled samples were low by comparison to other gravity separator effluents.

Miscellaneous Brine Tests

All other brine tests for BDCCF5 are listed in Tables 121, 122, and 123. The results for the following tests were in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content. These parameters will be discussed in a later section with respect to variations between platforms.

Crude Oil Tests

All crude oil test results are listed in Tables 124 and 125. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one or two and are of primary significance for comparisons between platforms.

Two equilibration tests were run, each at a different oil/water ratio.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil. Between platform comparisons will be presented in Section 17.

TABLE 120. BDCCF5 SUSCEPTIBILITY TO SEPARATION TESTS ON GRAVITY SEPARATOR INFLUENT

	Settling time, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 3, 1300								
IR-Oil, mg/l	152	121	121	91	78	62	56	156
IR-Oil W/Silica Gel, mg/l	104	-	61	-	-	-	44	-
Test Number 2 Day 5, 1000								
IR-Oil, mg/l	104	100	-	59	54	47	43	91
IR-Oil W/ Silica Gel, mg/l	69	-	-	-	-	-	37	-
Test Number 3 Day 6, 1300								
IR-Oil, mg/l	108	95	85	76	66	57	60	113
IR-Oil W/Silica Gel, mg/l	39	-	26	-	-	-	53	-
Average								
IR-Oil, mg/l	121	105	103	75	66	55	53	120
IR-Oil W/ Silica Gel, mg/l	71	-	44	-	-	-	45	-

TYPING GUIDE SHEET

TABLE 121. BDCCF5 SUPPLEMENTARY BRINE TESTS

Sample time Day	Sample time Hour	Temperature, °C 9--i	Temperature, °C 9--0	pH 9--0	Specific gravity[(1)] 9--0
01	08	42.0	42.0	6.8	1.091
02	08	40.5	40.0	6.7	1.094
03	08	41.5	41.0	6.8	1.094
04	08	41.0	41.5	6.7	1.094
05	08	39.5	39.5	6.6	1.098
06	08	41.0	40.5	6.8	1.094
07	08	41.5	40.5	6.6	1.095
08	08	42.0	42.0	6.7	1.097
09	08	40.5	40.0	6.6	1.095
10	08	41.5	41.5	6.7	1.094
Mean		41.1	40.9	6.7	1.095
Minimum		39.5	39.5	6.6	1.091
Maximum		42.0	42.0	6.8	1.098

Note: Sample point identification numbers (9--i, 9--0) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 122. BDCCF5 REDUCING BACTERIA

Sample point	Bacteria per milliliter
Heater Treater - Out (6A-0)	0
Heater Treater - Out (6B-0)	0
Gravity Separator - Out (8A-0)	10,000-100,000
Gravity Separator - Out (8B-0)	0
Flotation Unit - Out (9--0)	0

Sample Day and Hour: 09 at 15

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 123. BDCCF5 IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	38,250
Potassium (K)	256
Calcium (Ca)	1,360
Magnesium (Mg)	401
Barium (Ba)	98
Chloride (Cl)	71,200
Sulfate (SO_4)	6
Alkalinity (as HCO_3)	366
Iron (Total)	6
Sulfide (as H_2S)	0.15
Total Dissolved Solids	
Summation	112,000
Gravimetric	108,000

Sample Day and Hour: 08 at 13

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE 124. BDCCF5 CRUDE OIL MISCELLANEOUS TESTS(1)

Sample time Day	Sample time Hour	Temperature °C	Specific(2) gravity	Surface tension(3) dynes/cm
01	08	27.0	0.866	27
02	08	32.0	0.861	28
03	08	34.5	0.861	27
04	08	33.5	0.861	28
05	08	30.0	0.865	28
06	08	32.0	0.862	28
07	08	33.5	0.861	28
08	08	30.0	0.865	28
09	08	31.0	0.864	28
10	08	34.5	0.861	27
Mean		31.8	0.863	28
Minimum		27.0	0.861	27
Maximum		34.5	0.866	28

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
08	13	9.43	8.26

	Equilibration at 82°C Brine TDS = 112,000 mg/l	
Oil/Water Ratio	4/1	0.1/1
IR-Oil, mg/l	90	15
IR-Oil W/Silica Gel, mg/l	10	3
IR-Oil Filtered Brine, mg/l	81	17

---

(1) Samples taken from oil LACT unit.

(2) Specific gravity reported for temperature in table.

(3) Surface tension measured and reported at ambient temperatures from 19.5°C to 24.0°C.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTION HERE

TABLE 125. BDCCF5 CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	480
Boiling range, °C	**Percent recovered**
Below - 200	45.9
200 - 250	24.5
250 - 300	22.5
300 - 350	5.6
350 - 400	1.3
400 - 450	0.2
450 - 500	0.0
Total	100.0

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 12

PLATFORM SS107

GENERAL

The ten-day testing survey was conducted on Platform SS107 from March 6 through March 15, 1980.

A description of the production facilities, the test program, and data presentation and evaluation are presented in this section.

Four survey team members arrived at the platform on March 5 and the test equipment was set up the same day. Oil company personnel unloaded the equipment and provided living quarters, work space, sample taps, and the utilities needed to conduct the Program.

The complete testing survey was carried out without interruption by weather, operating problems, or for any other reason.

FACILITIES AND OPERATIONS

Production From Wells

Five wells were producing. Two wells were flowing by formation pressure, and the other three wells were gas lifted. Four wells shut in on Day 6 during the 0800 sample period. Three wells were opened after 15-20 minutes and the fourth after about one hour.

All production flowed or was gas lifted to the low-pressure gas/liquid separator. The average daily production calculated from well test data was 97 m^3/d (610 bpd) of oil, 633 m^3/d (3,979 bpd) of water, and 13,300 std m^3/d (470 Mcfd) of gas. The calculated water cut was 87 percent.

The measured oil production for the ten-day period averaged 89 m^3/d (560 bpd) or 8 percent less than the calculated production. The measured water production averaged 733 m^3/d (4,610 bpd) or 16 percent more than the calculated production.

Forty-two percent of the oil was gas lifted, and sixty-two percent of the water was gas lifted.

Production Process System

The flow of oil and water through the system is shown in Figure 75.

BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

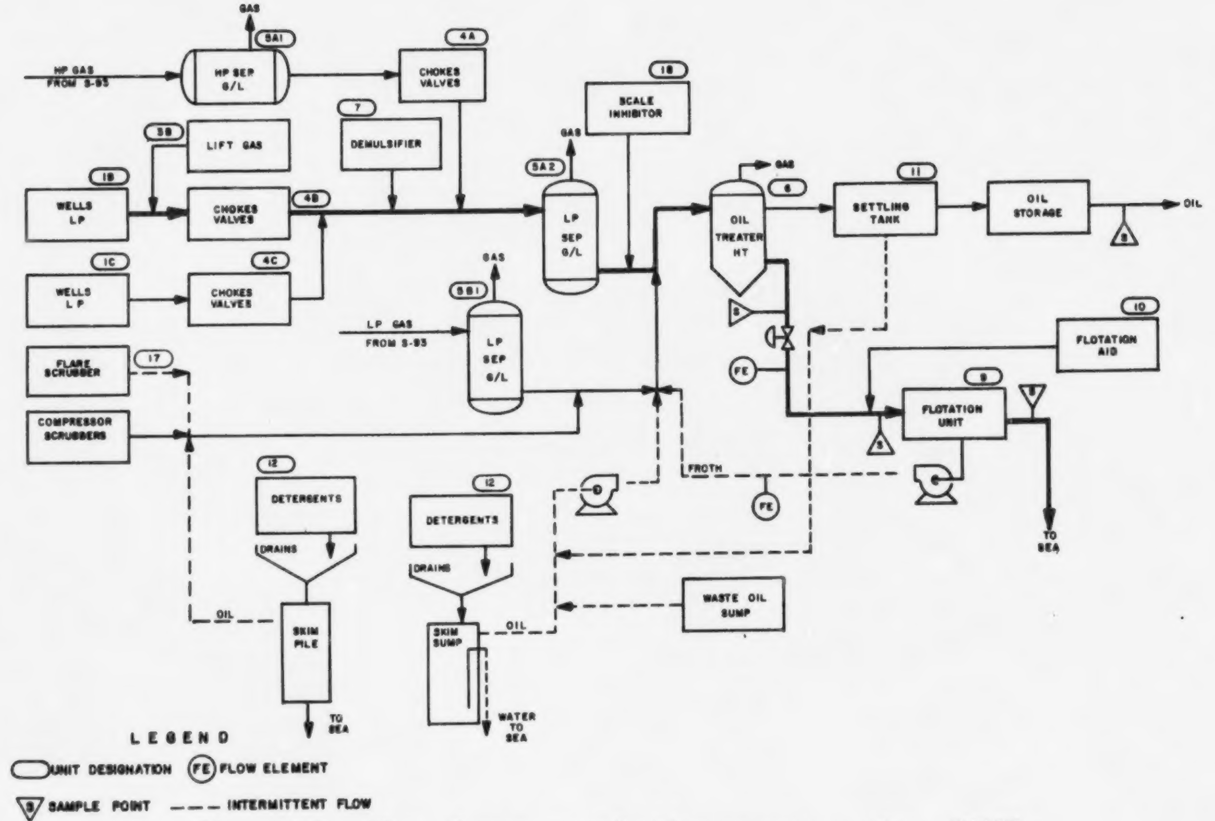

HP GAS FROM S-93
GAS
5A1
HP SEP G/L
4A
CHOKES VALVES
18
SCALE INHIBITOR
3B
LIFT GAS
7
DEMULSIFIER
GAS
5A2
GAS
6
11
1B
WELLS LP
CHOKES VALVES
4B
LP SEP G/L
OIL TREATER HT
SETTLING TANK
OIL STORAGE
OIL
1C
WELLS LP
4C
CHOKES VALVES
GAS
5B1
LP GAS FROM S-93
LP SEP G/L
10
FLOTATION AID
FE
FLARE SCRUBBER
17
9
FLOTATION UNIT
COMPRESSOR SCRUBBERS
FROTH
FE
12
DETERGENTS
12
DETERGENTS
TO SEA
DRAINS
DRAINS
WASTE OIL SUMP
OIL
SKIM PILE
OIL
SKIM SUMP
TO SEA
WATER TO SEA
LEGEND
UNIT DESIGNATION
FE FLOW ELEMENT
SAMPLE POINT
INTERMITTENT FLOW

Figure 75. Flow diagram, production process system, SS107.

Design and operating data on major vessels are presented in Table 126. The oil/water/gas flow is from the wells to the low-pressure gas-liquid separator. The high- and low-pressure gas from another platform flows through separators on SS107 before being compressed. The operator estimated that the liquids from these two separators would be about 3 m^3/d.

A demulsifier, Tretolite RN3003, is added to the produced fluids ahead of the low-pressure separator. A scale inhibitor, Tretolite SP175, is added to the fluids downstream of the low-pressure separator.

The fluids flow from the low-pressure separator to the oil treater. Oil flows from the treater to the settling tank. The water flows from the oil treater to the flotation unit and is then discharged.

Figure 76 is a flow schematic for the water streams to and from the oil treater and flotation unit. The primary flow is produced water from the low-pressure separator which averaged 874 m^3/d.

The liquid from the compressor scrubbers also flows to the oil treater. The operator estimated this flow to average 10 dm^3/d.

Miscellaneous open drains discharge to the skim sump or skim pile. Any oil that accumulates on the skim sump or pile is pumped to the oil treater at night. Settlement tank bottoms are pumped once per week at night.

The flow from the oil treater to the flotation unit was monitored continuously after 1300 on Day 1 with an orifice-plate type flow meter. The flotation unit froth was pumped to the oil treater. The froth flow was monitored for the first three days with a positive-displacement type flow meter. After 1300 on Day 3, the froth flow was estimated based on the time to fill the flotation unit launder. The effluent flow was calculated by subtracting the froth flow from the flotation unit inlet flow.

A water treating chemical, Tretolite FR 98D was added to the flotation unit influent. The addition rate varied from 4.5 dm^3/d (1.2 gpd) to 19 dm^3/d (5 gpd).

The oil treater is a dual purpose unit providing for the gravity separation of water from oil in preparation for sale of the oil. The treater also provides the primary separation of oil from water to prepare the water for treatment by flotation.

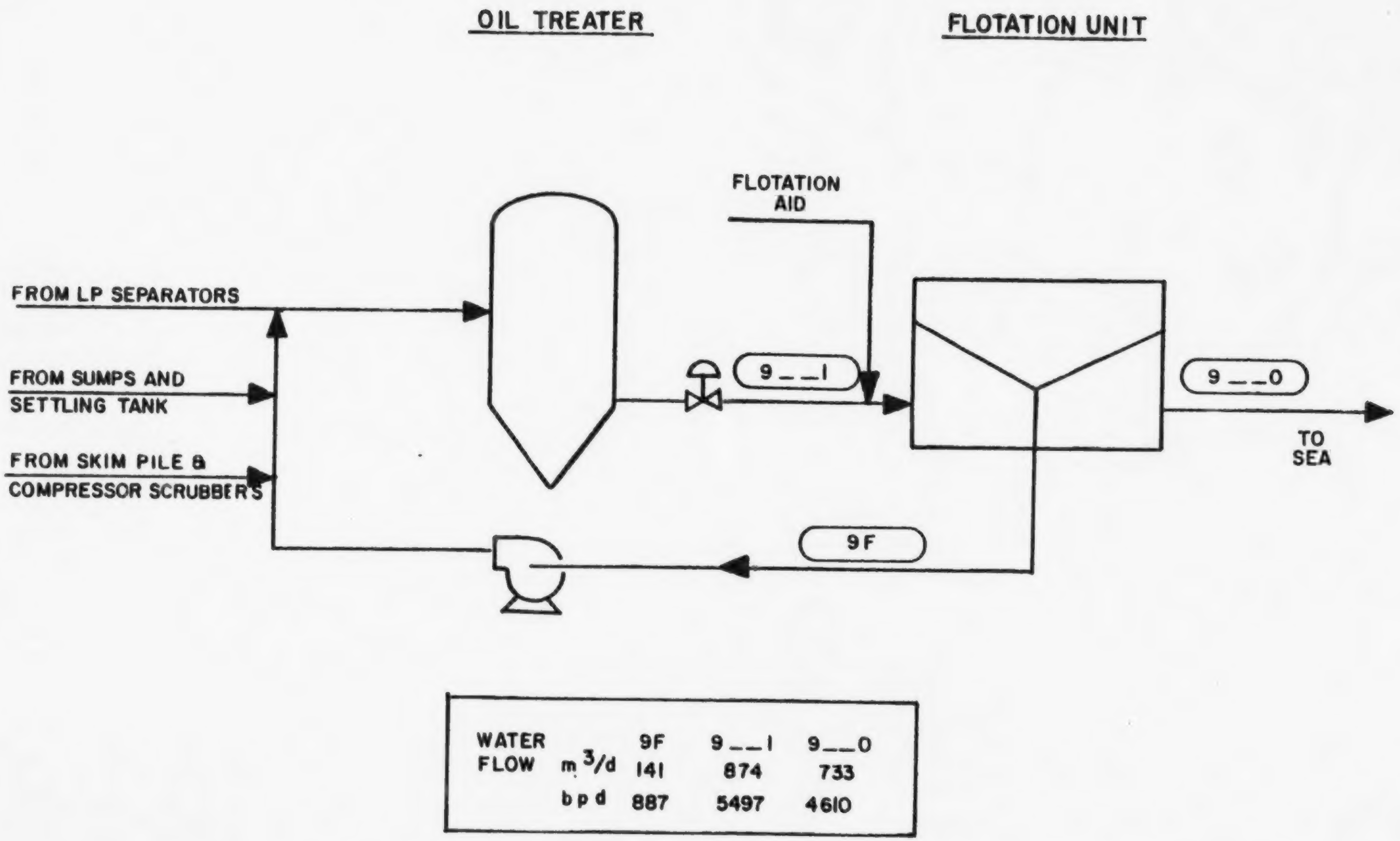
The oil treater is a vertical cylindrical cone-bottom tank. The treater is 3.05 m (10 ft) in diameter and 9.91 m (32.5 ft) seam to seam. The water outlet is near the bottom seam and the level control is with a valve. The water volume above the water outlet is 20 m^3 (126 bbl). At the average water flow rate of 874 m^3/d (5,497 bpd), the calculated average retention time would be 33 minutes.

The flotation unit (Wemco 1 + 1, Model 66) is a proprietary four-cell unit with mechanical gas eduction. This type of unit was described in Section 6 and is depicted in Figure 6. The design flow for the unit is 2,460 m^3/d

TABLE 126. SS107 VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 12-1			
	5A2 Low pressure 2-phase separator	5B1 Low pressure 2-phase separator	6 Oil treater	9 Flotation unit mechanical dispersed gas
Trade Name or Vessel Type	Vertical Cylinder	Vertical Cylinder	Vertical Cylinder Cone-Bottom	Wemco Model 66
Design Parameters				
Dimensions, m, (ft)				
Diameter, O.D.	1.3(4.3)	1.3(4.3)	3.05(10)	-
Length, S.S.	3.2(10.5)	3.2(10.5)	9.91(32.5)	-
Length	-	-	-	6.6(21.8)(1)
Width	-	-	-	1.7(5.5)(1)
Height				
Separation Surface Area, m^2, (ft^2)				
Total	-	-	7.30(78.5)	11.2(120)
Per Cell	-	-	-	2.8(30)
Separation Volume, m^3, (bbl)				
Total	-	-	-	6.8(43)
Oil Phase	-	-	-	-
Water Phase	-	-	20(126)	-
Number of Cells	-	-	-	4
Flow Rate, m^3/day, (bpd)	-	-	-	2,460(15,450)
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)(3)	-	-	-	880(515)
Recycle Rate, Percent of Flow	-	-	-	-
Retention Time, min.	-	-	-	4
Average Operating Parameters				
Temperature, $^oC(^oF)$	-	-	49.2(121)	48.2(119)
Pressure, kPag (psig)	600(87)	600(87)	150(22)	0(0)
Flow Rate, m^3/d (bpd)(2)	-	-	874(5,497)	733(4,610)
Flow Rate, Percent of Design	-	-	-	30
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)	-	-	120(70)	260(150)
Recycle Rate, Percent of Flow	-	-	-	-
Froth Flow, Percent of Flow	-	-	-	19

(1) Separation area.
(2) Effluent flow.
(3) Overflow rate is surface area divided by flow rate.


OIL TREATER
FLOTATION UNIT
FROM LP SEPARATORS
FROM SUMPS AND SETTLING TANK
FROM SKIM PILE & COMPRESSOR SCRUBBERS
FLOTATION AID
9__I
9__O
TO SEA
9F

WATER FLOW		9F	9__I	9__O
	m^3/d	141	874	733
	bpd	887	5497	4610

Figure 76. SS107 water handling system flow schematic.

(15,450 bpd). The average operating flow based on effluent flow was 733 m^3/d (4,610 bpd) or 30 percent of design flow. The average froth flow was 141 m^3/d or 19 percent of the forward flow.

SITE SPECIFIC TEST PROGRAM

The planned test program for brine samples was accomplished as presented in Table 127. The number of samples to be taken in ten days and the time the samples were to be taken each day are listed.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

Particle size distribution tests were run and are reported in Section 16.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operations are reported in this subsection.

Flow Monitoring

The flow from the oil treater to the flotation unit was monitored continuously as described in the subsection on the process system. The flotation froth was monitored the first three days with a flow monitor and estimated the remaining days. A flotation unit effluent flow and froth flow were calculated for each sample time. These flows are reported in Table 128.

The flotation unit/influent flow meter was not operational until the afternoon of the first day because of orifice plate changes. The flotation unit froth flow meter failed during the 1300 sample time on Day 3.

The water flow patterns are shown in Figure 75 and Figure 76. The primary flow is the produced water from the wells. The only other significant flow is the flotation unit froth return to the oil treater. The froth was pumped back to the treater using the flotation unit launder as a sump. The froth pump cycled on and off based on the liquid level in the launder. The froth pump capacity was 238 m^3/d (1,500 bpd).

Well Test Data

The well test data provided by the operator are presented in Table 129. The wells are grouped according to lift method.

Pressure Drops Through System

Table 130 traces pressure drops from the producing formation through the system.

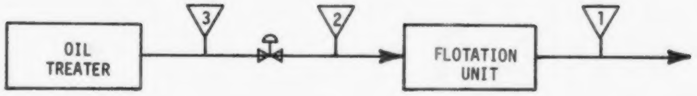


TABLE 127. SS107 TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS					
	1		2		3	
	9--0		9--1		6--0	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests						
Infrared Oil	40	8,10,13,15	-	-	40	8,10,13,15
Temperature	10	8	-	-	10	8
pH	10	8	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-
Water Surface Tension(2)	10	8	-	-	10	8
IR-Oil W/Silica Gel	20	8,13	-	-	10	8
IR-Oil Filtered Brine	20	8,13	-	-	10	8
Susceptibility to Separation(3)	-	-	-	-	3	13
Laboratory Tests						
Gravimetric Oil	40	8,10,13,15	-	-	10	8
Suspended Solids	10	8	-	-	10	8
Ionic Analysis	1	(1)	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.					
Particle Size Distribution(4)	3	13	3	13	3	13

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/silica gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/silica gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

TABLE 128. SS107 MAJOR BRINE TESTS

Sample time		Flotation unit influent (9--i)						Flotation unit effluent (9--0)							
				IR-Oil w/silica gel						IR-Oil w/silica gel				Flow rate	
		GR-Oil	IR-Oil	Dispersed	Soluble	Filtered brine IR-Oil	Surface tension	GR-Oil	IR-Oil	Dispersed	Soluble	Filtered brine IR-Oil	Surface tension	Out	Skimmings
Day	Hour	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	197	203	34	169	31	55	12	26	3	23	25	66	-	205
01	10	-	389	-	-	-	-	15	29	-	-	-	-	-	102
01	13	-	212	-	-	-	-	14	15	0	15	30	-	-	120
01	15	-	212	-	-	-	-	101(C)	144(C)	-	-	-	45(C)	728	101
02	08	137	203	34	169	32	52	4	15	0	15	28	65	748	238
02	10	-	186	-	-	-	-	5	14	-	-	-	-	749	210
02	13	-	254	-	-	-	-	7	15	0	15	30	-	743	215
02	15	-	195	-	-	-	-	5	15	-	-	-	-	754	222
03	08	171	216	15	201	34	49	5	14	1	13	30	62	763	159
03	10	-	195	-	-	-	-	3	12	-	-	-	-	747	156
03	13	-	157	-	-	-	-	4	12	0	12	31	-	726	159
03	15	-	127	-	-	-	-	8	19	-	-	-	-	597	159
04	08	120	119	80	39	31	46	10	11	0	11	32	64	738	238
04	10	-	212	-	-	-	52	9	20	-	-	-	-	725	141
04	13	-	224	-	-	-	-	18	17	5	12	32	-	736	75
04	15	-	250	-	-	-	-	7	13	-	-	-	-	761	68
05	08	126	186	131	55	41	54	6	16	3	13	31	62	760	51
05	10	-	203	-	-	-	-	6	15	-	-	-	-	731	61
05	13	-	199	-	-	-	-	31	14	3	11	33	-	738	55
05	15	-	195	-	-	-	-	6	15	-	-	-	-	744	48
06	08	248	144	85	59	24	50	4	11	0	11	37	67	683	238
06	10	-	135	-	-	-	-	3	10	-	-	-	-	738	238
06	13	-	203	-	-	-	-	6	14	1	13	27	-	758	164
06	15	-	186	-	-	-	-	4	10	-	-	-	-	717	223
07	08	184	246	178	68	39	42	7	15	2	13	30	60	727	157
07	10	-	229	-	-	-	-	4	10	-	-	-	-	724	161
07	13	-	195	-	-	-	-	5	14	1	13	32	-	722	181
07	15	-	203	-	-	-	-	6	13	-	-	-	-	729	193
08	08	163	220	161	59	39	46	5	14	3	11	32	63	729	137
08	10	-	220	-	-	-	-	4	14	-	-	-	-	723	143
08	13	-	195	-	-	-	-	9	16	3	13	35	-	723	125
08	15	-	237	-	-	-	-	6	12	-	-	-	-	725	123
09	08	139	207	131	76	41	42	6	14	0	14	33	61	735	75
09	10	-	229	-	-	-	-	7	14	-	-	-	-	737	83
09	13	-	254	-	-	-	-	5	14	3	11	33	-	745	84
09	15	-	254	-	-	-	-	15	13	-	-	-	-	736	91
10	08	183	279	207	72	39	48	6	14	1	13	34	62	744	122
10	10	-	254	-	-	-	-	5	14	-	-	-	-	751	115
10	13	-	330	-	-	-	-	6	14	2	12	34	-	745	103
10	15	-	237	-	-	-	-	7	14	-	-	-	-	750	98
Minimum		120	119	15	39	24	42	3	10	0	11	25	60	597	48
Maximum		248	389	207	201	41	55	31	29	5	23	37	67	763	238

(C) Not included in statistical analysis. The system was upset by a shutdown to install an orifice for survey flow monitoring

TABLE 129. SS107 WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig		Choke size 1/64 in.	API gravity
							SIBHP	FTP		
Flowing to Low Pressure Separator										
11-		9,752	198	265	1,205	0	3,980	160	open	35.1
13-		9,720	62	92	292	0	4,200	440	15	35.1
Total (Average)		-	260	357	1,497	0	-	-	-	(35.1)
Gas Lift to Low Pressure Separator										
1-		10,162	124	128	1,470	344	4,080	203	open	33.0
6C		9,737	71	64	999	145	4,000	106	open	36.7
34		9,270	15	64	16	286	3,500	109	open	36.2
Total (Average)		-	210	256	2,485	775	-	-	-	(35.3)
Combined Total (Average)		-	470	613	3,982	775	-	-	-	(35.2)

TABLE 130. SS107 PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Formation (SIBHP)	24,100-29,000 (3,500-4,200)	perforations, static head, pipes	23,400-26,800 (3,390-3,890)
Flowing Tubing Pressure	730-3,030 (106-440)	chokes, valves, pipes	130-2,430 (19-353)
Low Pressure Separator	531-696 (77-101)	control valve, pipes	381-546 (55-79)
Oil Treater	140-170 (20-25)	control valve, orifice plate, pipes	140-170 (20-25)
Flotation Unit	0		

Table 130 shows that the greatest pressure drops occur from the formation to the chokes, substantial drops occur at the chokes, and more minor drops from the chokes on.

Chemical Addition

Four chemicals were added by metering pumps. Chemical usage was monitored daily by noting the volume of chemical remaining in the feed pump reservoir.

A flotation aid, Tretolite FR 98D, was added about one meter upstream of the flotation unit. The addition rate was not uniform. An addition rate for each day is presented in Table 131.

The usage of other chemicals is shown in Table 132.

Observations and Operator Reports

An effort was made to record any event that could affect effluent oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures and the survey team made their own observations.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 131. SS107 FLOTATION CHEMICAL ADDITION

Day	Addition rate dm^3/d	 ppmv(1)
01	7.4	10.2
02	5.1	6.9
03	4.5	6.4
04	5.6	7.6
05	7.5	10.1
06	-	-
07	17.1	23.6
08	18.6	25.7
09	19.0	25.7
10	8.6	11.4
Mean	10	14

(1) Based on average water flow through the flotation unit for each day.

TABLE 132. SS107 CHEMICAL ADDITION

Chemical	Addition point	Addition rate dm^3/d	 ppmv
Methanol	Lift gas	8.0(1)	-
Tretolite RN3003 (Demulsifier)	Well Manifold ahead of 5A2	8.6	8.9(2)
Tretolite SP175 (Scale inhibitor)	Low Pressure separator outlet	7.3	7.5(2)

(1) Stopped injecting methanol on Day 9.
(2) Based on average fluid flow through the oil treater.

After the 1300 sample time on Day 1, the level in the oil treater was lowered in preparation for changing the orifice plate between the oil treater and the flotation unit. The flow to the flotation unit was stopped for about 45 minutes after the liquid level in the oil treater was lowered. The flow to the flotation unit was resumed an hour before the 1500 samples were taken.

The flow to the flotation unit was stopped for about 10 minutes after the 0800 sample time on Day 3. The flow was stopped to allow a leak in the line to be repaired.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

The froth flow meter failed on Day 3 during the 1300 sample period. The flow meter was a positive displacement meter and the failure blocked the line. The recycle of the froth to the oil treater was resumed at 1615 on Day 3.

All wells except Well 34 shut in during the 0800 sample period on Day 6. Wells 6c, 11 and 13 were shut in for 15-20 minutes. Well 34 was shut in for 1-1½ hours.

The only rain was on Day 6 at 1630. Deck washings took place on Day 6 and 7. The effect of rain, deck washings, and settlement tank bottoms is not known because these liquids were pumped into the system at night. A few cubic meters of oil and water was pumped off the skim sump on nights 7 and 9. On night 9, a few cubic meters of liquid was pumped off the skim pile and about 20 cubic meters of liquid off the settlement tank bottom.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables, summary tables and graphs for SS107 are interspersed in the text.

Effluent Oil Content

Table 128 presents a listing of oil content test results for the major sampling points. Figure 77 presents a plot of GR-Oil in and out of the flotation unit versus time. Figure 78 presents the same plot for IR-Oil content. The time-indexed plots are based on four test results per day, except for the flotation unit influent GR-Oil.

The tabulated data and time-indexed plots show that the flotation unit influent is relatively uniform with only two of the 40 IR-Oil contents over 300 mg/l. The flotation unit effluent oil content is exceptionally uniform except for Day 1 at 1500. The high oil content at 1500 followed the changing of the orifice plate in the flow meter monitoring the oil treater effluent water flow. The oil treater liquid level had been lowered and the flow to the flotation unit had been stopped prior to changing the orifice plate. Although the 1500 flotation unit influent IR-Oil does not indicate that the oil treater is upset, it is believed that the flotation unit had not yet recovered.

The ranges of test results, not including Day 1 at 1500, are as follows:

Flotation Effluent GR-Oil - 3 to 31 mg/l,
Flotation Effluent IR-Oil - 10 to 29 mg/l,
Flotation Influent GR-Oil - 120 to 248 mg/l,
Flotation Influent IR-Oil - 119 to 389 mg/l.

Flotation unit effluent oil content histograms for the two test methods are presented in Figure 79 and Figure 80. Figure 81 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

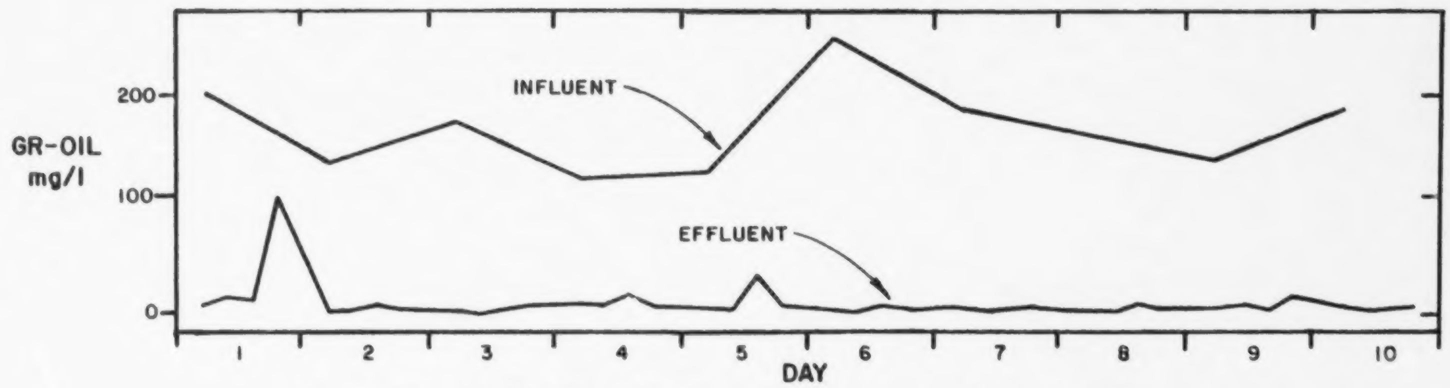


Figure 77. SS107 flotation unit performance, GR-oil vs time.

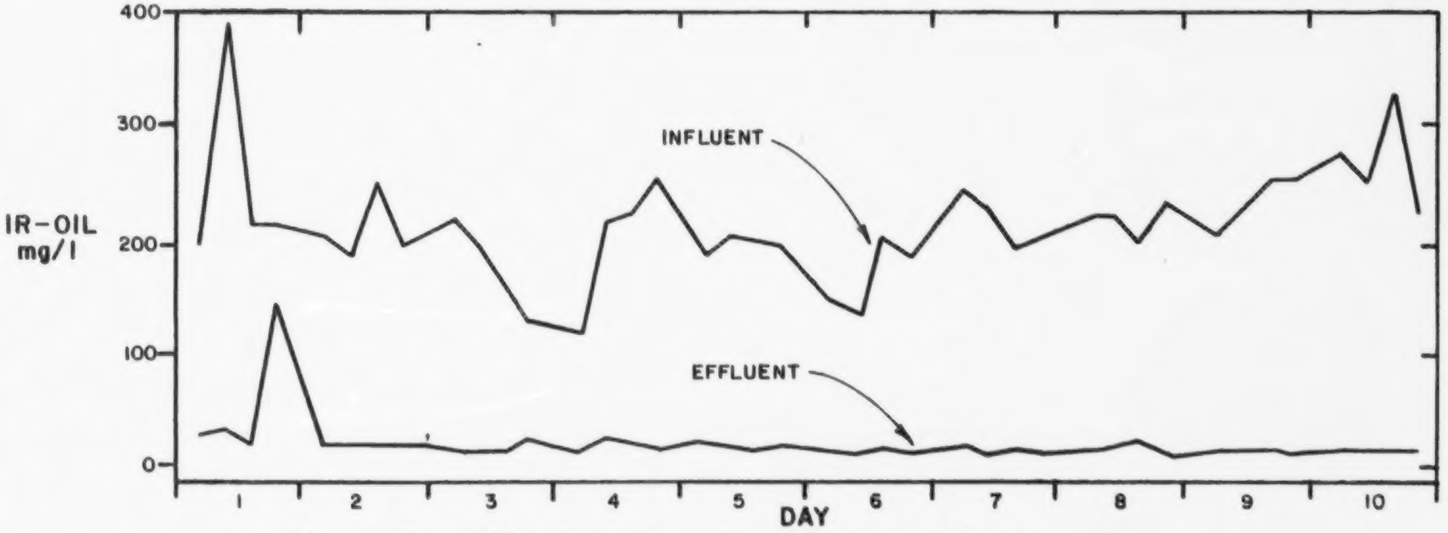


Figure 78. SS107 flotation unit performance, IR-oil vs time.

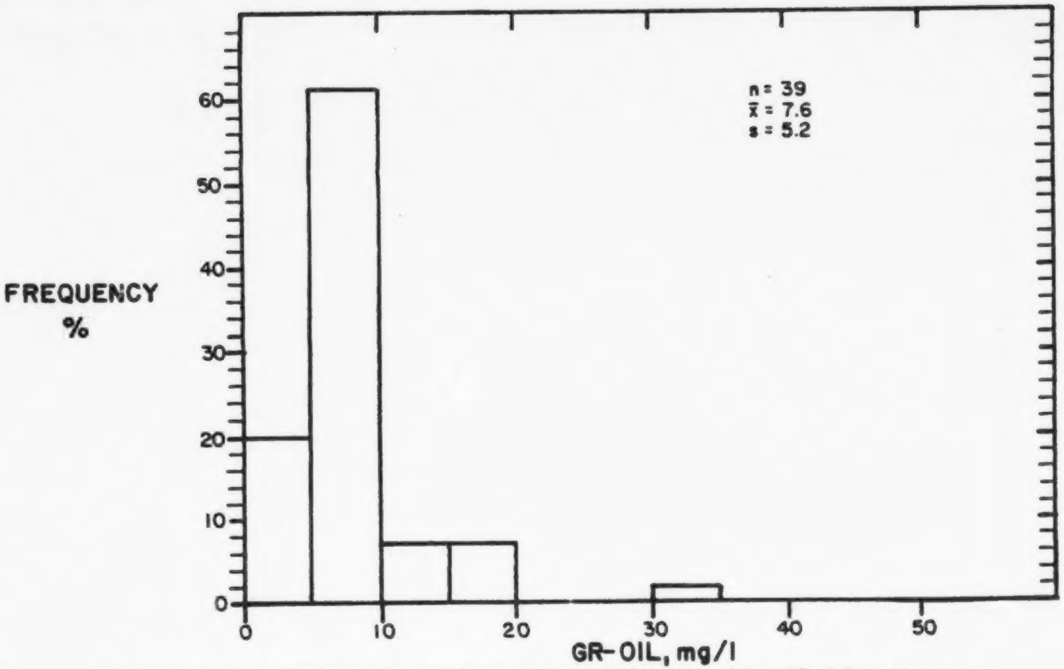


Figure 79. SS107 flotation unit effluent, GR-oil histogram.

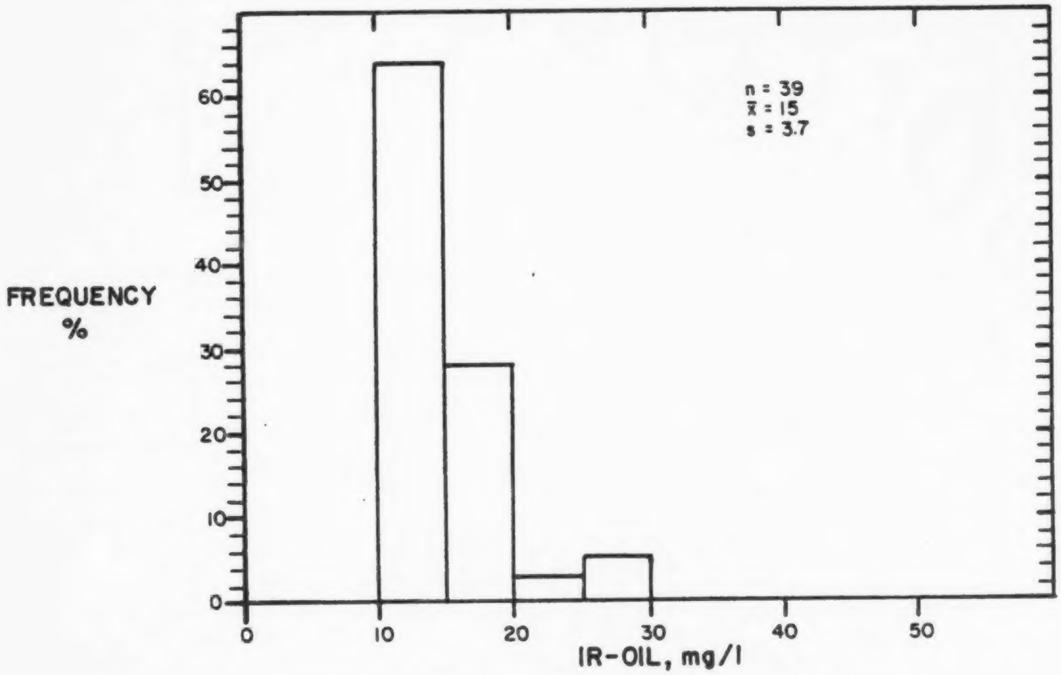


Figure 80. SS107 flotation unit effluent, IR-oil histogram.

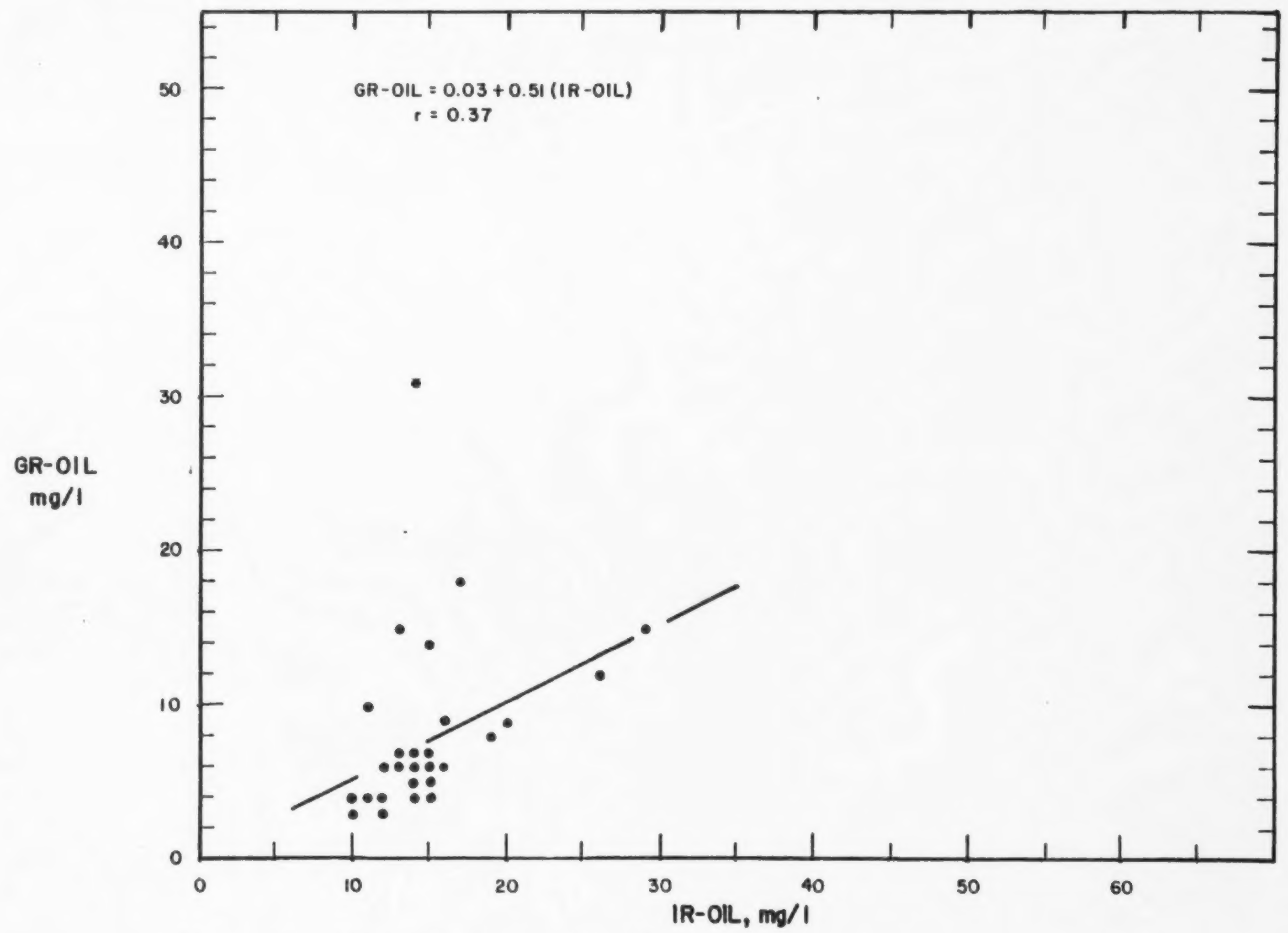


Figure 81. SS107 flotation unit effluent, infrared-gravimetric regression.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
6-1/2"

time dependent sample differences as well as normal sampling and testing variations.

Table 133 presents a summary comparison of test results by the two methods.

TABLE 133. SS107 FLOTATION UNIT EFFLUENT
GR-OIL AND IR-OIL COMPARISON

	Oil content GR-Oil	 IR-Oil
Number of tests, (n)	39	39
Mean, ($\bar{x}$), mg/l	8	15
Minimum, mg/l	3	10
Maximum, mg/l	31	29
Standard Deviation,(s), mg/l	5.2	3.7
	Paired tests	
Number, (n)	39	
Mean of Differences, ($\bar{\Delta}$), mg/l	8.1	
Standard Deviation, (s_{Δ}), mg/l	3.3	

The data presented in Table 133 and the histograms indicate that the mean oil content is higher by the IR-Oil test method than by the GR-Oil test method. However, the scatter of the data in the regression plot, Figure 81 and the correlation coefficient of 0.37 indicate only limited correlation.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 128. A summary of these test results on the flotation unit effluent is presented in Table 134.

TABLE 134. SS107 SOLUBLE OIL SUMMARY

	Flotation effluent		
Analysis or test	Range mg/l	Mean mg/l	Proportion of total, percent
IR-Oil	11-26	14.8	100
Dispersed Oil	0-5	1.6	11
Soluble Oil	11-23	13.2	89

Note: Table includes only IR-Oil tests when an IR-Oil w/Silica Gel test was run.

An average of 89 percent of the oil in the effluent was soluble oil and 11 percent was dispersed oil.

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 82. Extrapolations of the linear regression lines to zero dispersed oil indicate a residual IR-Oil of 13 mg/l and a residual GR-Oil of 6 mg/l after all dispersed oil is removed. The mean soluble oil content of the flotation unit effluent was 13 mg/l.

The mean soluble oil content of the flotation unit influent was 97 mg/l, which is significantly higher than the mean of 13 mg/l of the flotation unit effluent.

Surface Tension

All surface tension test results are listed in Table 128. The mean surface tension of the flotation influent is 49 dynes/cm and of the flotation effluent is 63 dynes/cm. The range for flotation effluent test results was from 60 to 67 dynes/cm not including the Day 1, 1500 sample. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 403 - 6.1\ (\text{Surface Tension})$$
$$r = -0.92$$

The test result on Day 1 at 1500 after the orifice plate was changed was included in calculating the regression equation. A decrease in IR-Oil content of 6.1 mg/l is indicated for each 1 dyne/cm increase in surface tension.

Suspended Solids

The suspended solids tests were run on the flotation unit influent and effluent. Total suspended solids and Freon soluble suspended solids data were not obtained because of problems in completing the analyses. The data obtained are recorded in Table 135 and a suspended solids summary for SS107 is presented in Table 136.

The data in Table 136 indicate that all of the solids were acid soluble. The average suspended solids reduction across the flotation unit was 60 percent.

Figure 83 presents time-indexed plots of Freon insoluble suspended solids in the flotation unit influent and effluent, and of flotation effluent dispersed oil. All samples were taken at the same time, 0800 each day. The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when suspended solids are higher in the flotation unit influent or effluent. As discussed in Section 18, the suspended solids test method may not have sufficient precision to provide meaningful results at the solids concentration in the SS107 brine.

Filtered Brine

The filtered brine IR-Oil content of SS107 effluent was in the range of 15 to 37 mg/l with a mean of 31 mg/l. The mean effluent IR-Oil content of unfiltered brine on SS107 was 15 mg/l for samples when filtered brine tests were also run. The fact that the measured oil content of filtered brine was

EPA-287 (Cin.)
(4-76)

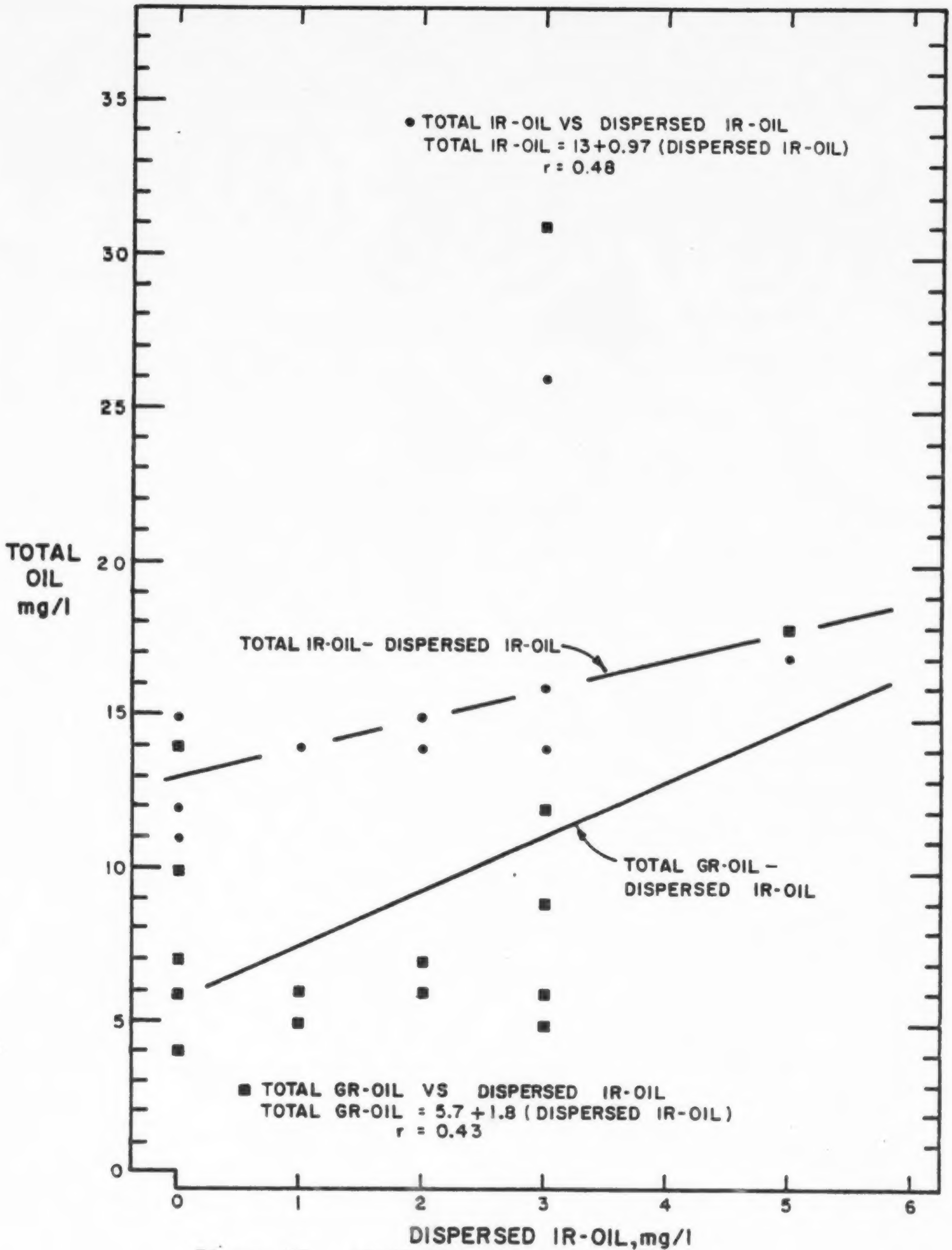


Figure 82. SS107 flotation unit effluent, total oil - dispersed oil regression.

TABLE 135. SS107 SUSPENDED SOLIDS TESTS

Sample time		Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	-	-	8	8	0	-	-	5	5	0
02	08	-	-	17	17	0	-	-	6	6	0
03	08	-	-	22	22	0	-	-	7	7	0
04	08	-	-	18	18	0	-	-	10	10	0
05	08	-	-	13	13	0	-	-	7	7	0
06	08	-	-	15	15	0	-	-	4	4	0
07	08	-	-	23	23	0	-	-	1	0	1
08	08	-	-	11	11	0	-	-	7	7	0
09	08	-	-	7	7	0	-	-	9	9	0
10	08	-	-	11	11	0	-	-	8	8	0
Minimum		-	-	7	7	0	-	-	1	0	0
Maximum		-	-	23	23	0	-	-	10	10	1

TABLE 136. SS107 SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 9--i	Average suspended solids, mg/l 9--0
Freon Insoluble	15	6
Acid Soluble	15	6
Fixed	0	0

consistently higher than that for unfiltered brine indicates a bias to the high side for the filtered brine tests run on SS107 effluent.

The filtered brine mean IR-Oil content of the flotation influent was 35 mg/l, which was very close to the mean effluent filtered brine oil content.

Flotation Unit Performance

Figure 84 is a regression plot of IR-Oil in and out of the flotation unit. The slope of the linear regression line is only 0.03 indicating little or no effect of influent oil on effluent oil.

Figure 85 is a regression plot of flotation unit effluent IR-Oil content and percent hydraulic loading. A similar plot for the gravity separator effluent is also presented. The slope of the linear regression line is -0.39, indicating a slight negative relationship between hydraulic loading and effluent oil.

The lack of expected relationships between effluent oil and influent oil or hydraulic loading may be because of the stable influent oil (119 mg/l to

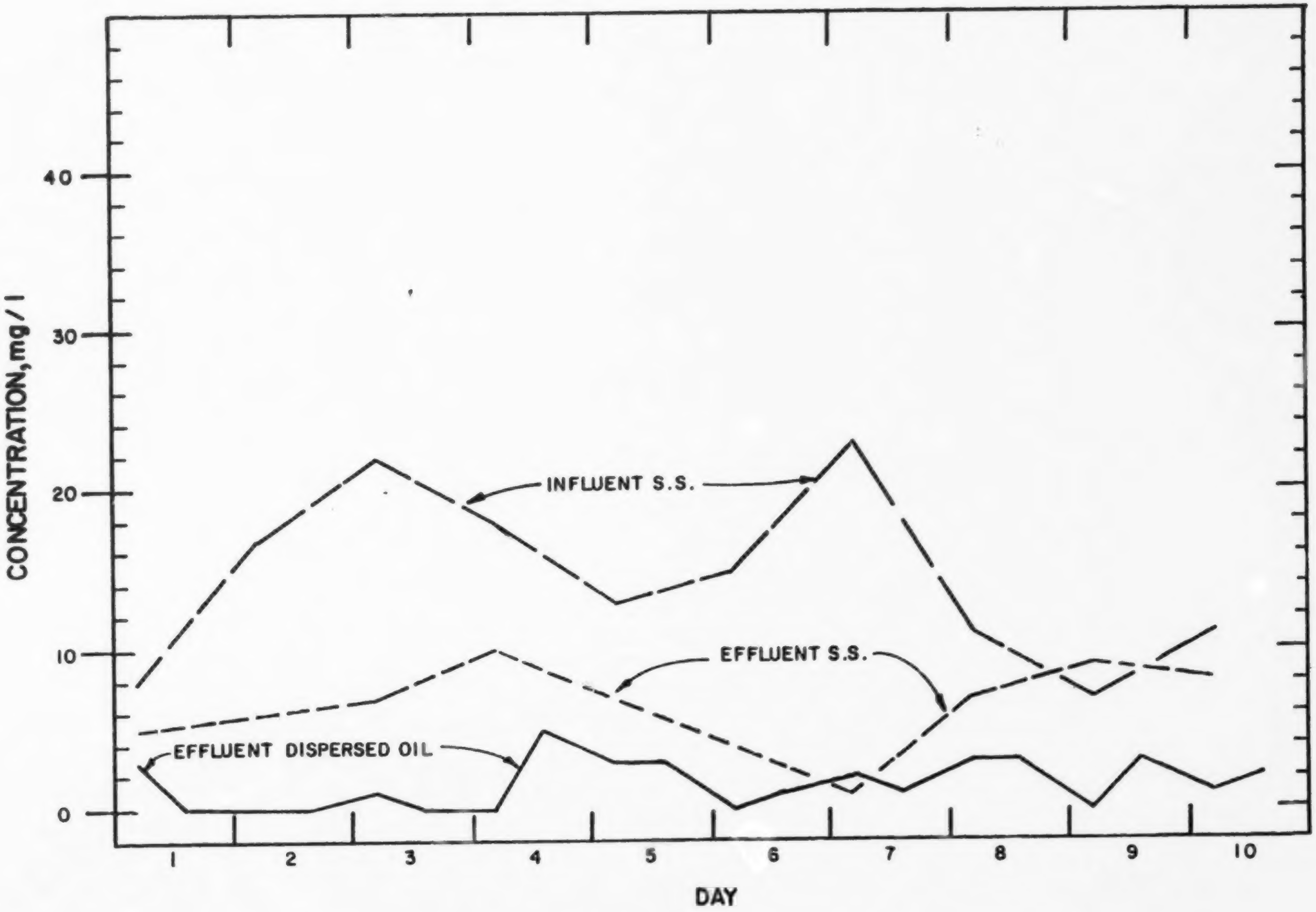


Figure 83. SS107 flotation unit Freon insoluble suspended solids.

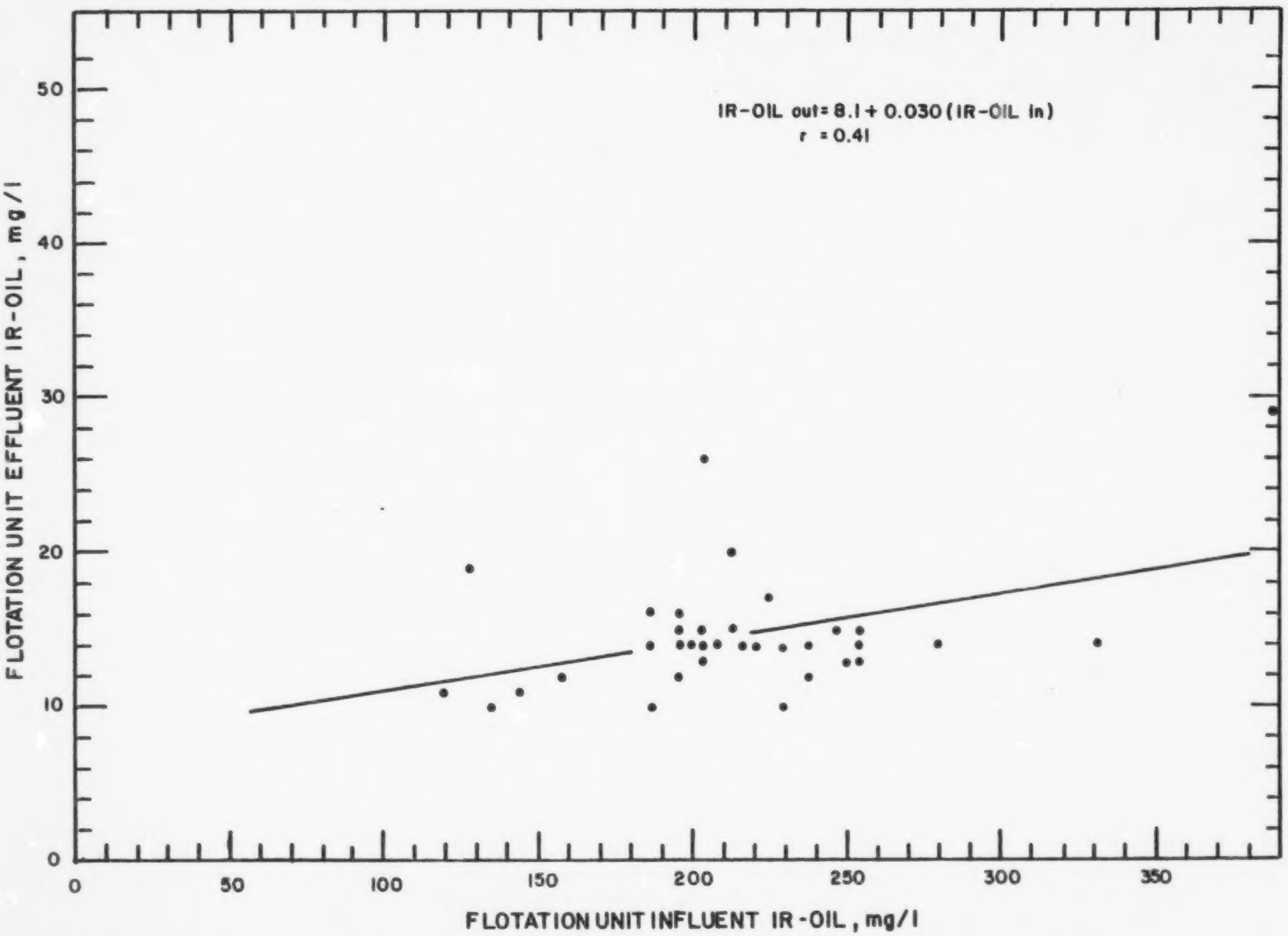


Figure 84. SS107 flotation unit in-out IR-oil regression.

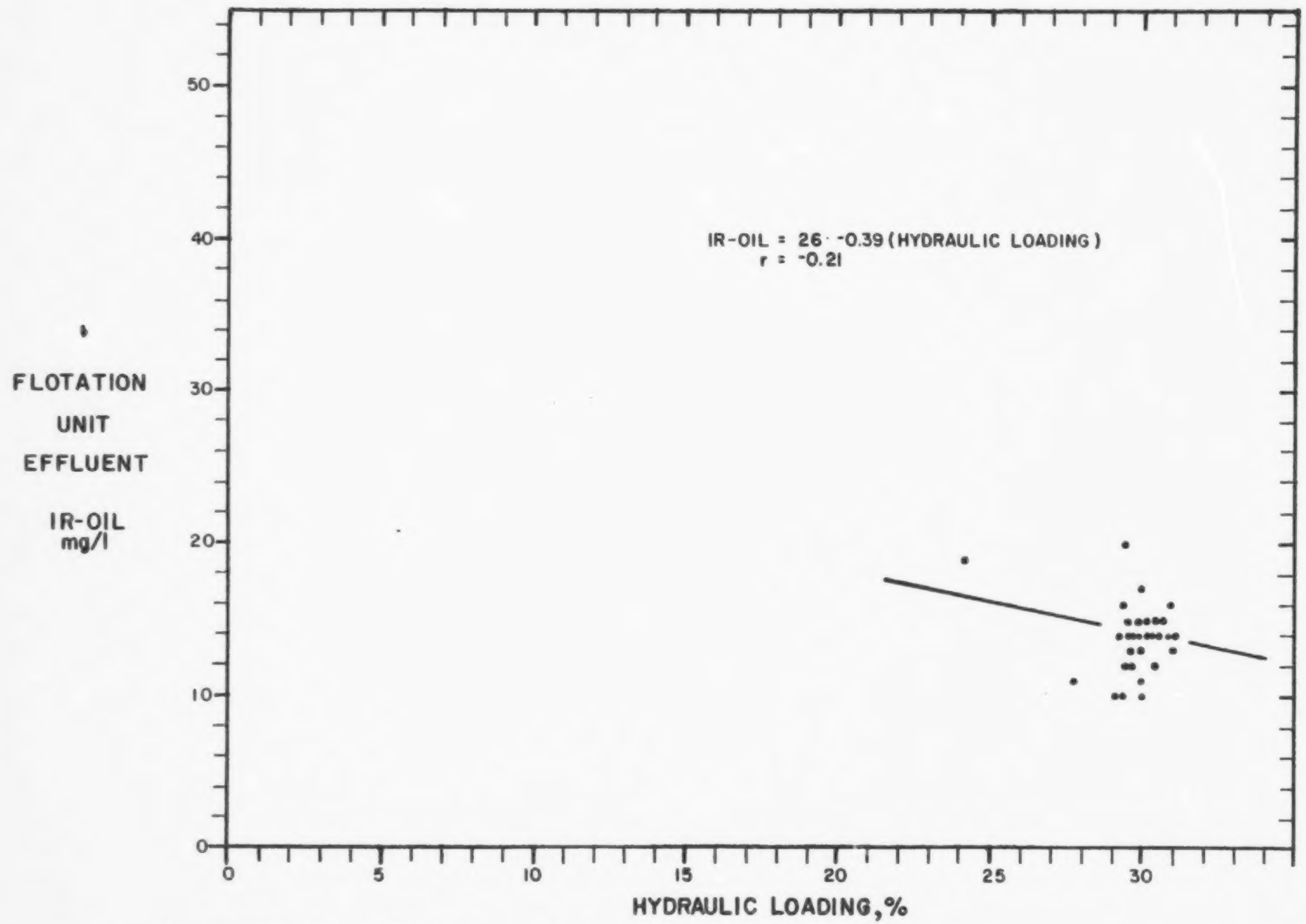


Figure 85. SS107 flotation unit hydraulic loading - infrared oil regression.

389 mg/l) and the moderately low hydraulic loading. The hydraulic loading was in the range of 24 to 31 percent of the design capacity.

Oil Treater Performance

The sample point for the oil treater effluent is the same as for the flotation unit influent (9--i). The treater effluent oil content data are presented in Table 128. The treater effluent mean IR-Oil content was 215 mg/l.

The results of the susceptibility to separation tests on the treater effluent are presented in Table 137. The mean IR-Oil content after 15 minutes of settling was 103 mg/l. If the 103 mg/l is compared to the treater effluent mean IR-Oil of 215 mg/l, it indicates that additional oil could be removed by static settling.

The largest oil drop measured by the particle size test in the oil treater effluent had a diameter of 35 μm.

Miscellaneous Brine Tests

All other brine test results for SS107 are listed in Tables 138, 139, and 140. The results for the following tests were generally in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content. These parameters will be discussed in a later section with respect to variations between platforms.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on SS107. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil test results are listed in Tables 141 and 142. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges with the exception of one temperature reading.

The viscosity and boiling range distribution tests were limited in number to one and are of primary significance for comparisons between platforms. Two equilibration tests were run, each at a different oil/water ratio.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil. Between-platform comparisons will be presented in Section 17.

TABLE 137. SS107 SUSCEPTIBILITY TO SEPARATION TESTS OIL TREATER EFFLUENT

	Settling times, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 4, 1000								
IR-Oil, mg/l	212	127	127	110	89	47	127	254
IR-Oil W/Silica Gel, mg/l	153	-	76	-	-	-	64	-
Test Number 2 Day 6, 1000								
IR-Oil, mg/l	136	102	93	85	76	63	56	153
IR-Oil W/Silica Gel, mg/l	68	-	34	-	-	-	40	-
Test Number 3 Day 8, 1000								
IR-Oil, mg/l	220	127	136	114	102	85	75	237
IR-Oil W/Silica Gel, mg/l	170	-	85	-	-	-	60	-
Average								
IR-Oil, mg/l	189	119	119	103	89	65	86	215
IR-Oil W/Silica Gel, mg/l	130	-	65	-	-	-	55	-

TABLE 138. SS107 SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °C		pH	Specific gravity(1)
Day	Hour	9--i	9--0	9--0	9--0
01	08	40.5	39.0	6.7	1.099
02	08	49.5	48.0	6.5	1.089
03	08	49.0	49.5	6.3	1.089
04	08	49.5	50.5	6.9	1.094
05	08	51.0	50.0	6.7	1.099
06	08	52.0	51.0	6.8	1.093
07	08	52.0	51.0	6.8	1.094
08	08	50.0	49.0	6.4	1.099
09	08	48.0	46.5	6.8	1.094
10	08	50.0	47.0	6.5	1.099
Mean		49.2	48.2	6.6	1.095
Minimum		40.5	39.0	6.3	1.089
Maximum		52.0	51.0	6.9	1.099

Note: Sample point identification numbers (9--i, 9--0) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 139. SS107 IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	40,000
Potassium (K)	340
Calcium (Ca)	3,500
Magnesium (Mg)	740
Barium (Ba)	198
Chloride (Cl)	61,600
Sulfate (SO_4)	5
Alkalinity (as HCO_3)	464
Iron (Total)	9
Sulfide (as H_2S)	0.14
Total Dissolved Solids	
Summation	106,000
Gravimetric	112,000

Sample Day and Hour: 09 at 13

TABLE 140. SS107 SULFATE REDUCING BACTERIA

Sample point	Bacteria per milliliter
Oil Treater - Out (6--0)	0
Flotation Unit - Out (9--0)	0

Sample Day and Hour: 07 at 13

TABLE 141. SS107 CRUDE OIL MISCELLANEOUS TESTS(1)

Sample time Day	Hour	Temperature °C	Specific(2) gravity	Surface tension(3) dynes/cm
01	08	38.5	0.838	27
02	08	42.5	0.825	26
03	08	44.0	0.822	26
04	08	44.5	0.824	25
05	08	48.0	0.821	26
06	08	45.5	0.822	26
07	08	47.0	0.824	26
08	08	45.0	0.824	27
09	08	44.0	0.825	27
10	08	46.0	0.824	27
Mean		44.5	0.825	26
Minimum		38.5	0.821	25
Maximum		48.0	0.838	27

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
09	13	4.34	3.71

	Equilibration at 82°C Brine TDS = 106,000 mg/l	
Oil/Water Ratio	4/1	0.15/1
IR-Oil, mg/l	12	14
IR-Oil W/Silica Gel, mg/l	8	2
IR-Oil Filtered Brine, mg/l	12	8

---

(1) Samples taken from oil treater.
(2) Specific gravity reported for temperature in table.
(3) Surface tension measured and reported at ambient temperatures from 19.0° to 24.0°C.

TABLE 142. SS107 CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	500
Boiling range, °C	**Percent recovered**
Below - 200	38.2
200 - 250	24.3
250 - 300	25.5
300 - 350	6.3
350 - 400	3.0
400 - 450	2.0
450 - 500	0.7
Total	100.0

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

SECTION 13

PLATFORM SS198G

GENERAL

The ten-day testing survey was conducted on Platform SS198G from March 17 through March 26, 1980.

A description of the production facilities, the test program, and data presentation and evaluation are presented in this section.

Four survey team members arrived at the platform on March 16 and the test equipment was set up the same day. Oil company personnel unloaded the equipment and provided living quarters, work space, sample taps, and the utilities needed to conduct the Program.

The complete testing survey was carried out without interruption by weather, operating problems, or for any other reason.

FACILITIES AND OPERATIONS

Production From Wells

Five wells were producing. Only one of the wells was an oil well. It flowed to the low-pressure gas-liquid separator. The other four wells were high-pressure gas wells which flowed to the high-pressure separator. The liquid from the high-pressure separator was manually drained to the low-pressure separator once or twice per week.

Three gas lift wells were shut in because the low-pressure gas compressor went down two days before the survey team arrived. Only minor interruptions in production occurred during the ten-day test survey.

The average daily production calculated from well test data was 94 m^3/d (593 bpd) of oil, 31 m^3/d (195 bpd) of water, and 405,000 std m^3/d (14,320 Mcfd) of gas. The calculated water cut based on this data was 25 percent.

The measured oil production for the ten-day period averaged 99 m^3/d (623 bpd) or 5 percent more than the well test data. The water production was estimated at 11.8 m^3/d (74 bpd) or 62 percent less than the well test data.

Production Process System

The flow of oil and water through the system is shown in Figure 86.

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

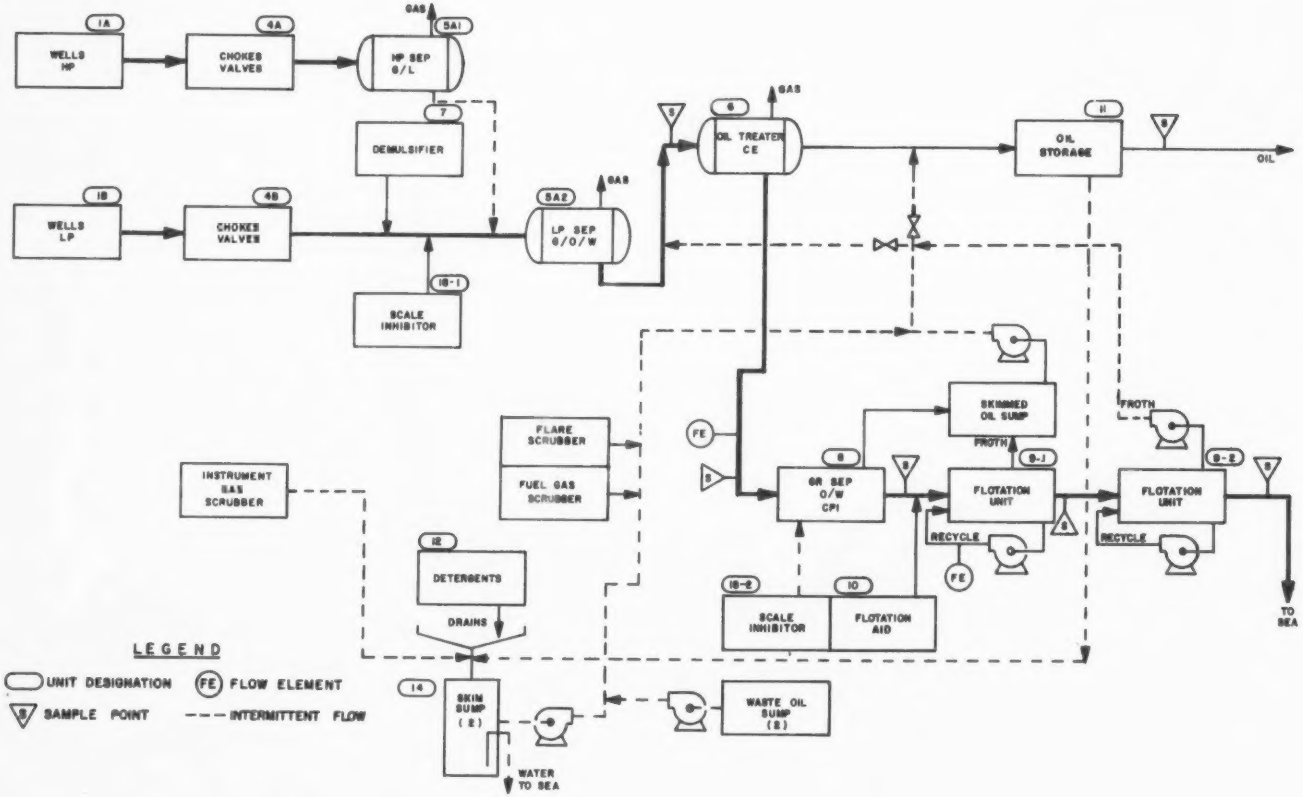

WELLS HP
1A
CHOKES VALVES
4A
HP SEP G/L
5A1
GAS
7
DEMULSIFIER
WELLS LP
1B
CHOKES VALVES
4B
18-1
SCALE INHIBITOR
LP SEP G/O/W
5A2
GAS
OIL TREATER CE
6
GAS
OIL STORAGE
11
OIL
FLARE SCRUBBER
FUEL GAS SCRUBBER
INSTRUMENT GAS SCRUBBER
FE
GR SEP O/W CPI
8
SKIMMED OIL SUMP
FROTH
FLOTATION UNIT
9-1
RECYCLE
FE
FROTH
FLOTATION UNIT
9-2
RECYCLE
TO SEA
18-2
SCALE INHIBITOR
10
FLOTATION AID
12
DETERGENTS
DRAINS
14
SKIM SUMP (2)
WATER TO SEA
WASTE OIL SUMP (2)
LEGEND
UNIT DESIGNATION
FE FLOW ELEMENT
SAMPLE POINT
INTERMITTENT FLOW

Figure 86. Flow diagram, production process system, SS198G.

Design and operating data on major vessels are presented in Table 143. The oil/water/gas flow is from the well to the low-pressure gas-liquid separator.

A demulsifier, Tretolite RP2327, and a scale inhibitor, Tretolite SP246, are added to the produced fluids at the well manifold ahead of the low-pressure separator.

The fluids flow from the low-pressure separator to the electrostatic oil treater. Oil flows from the treater to the storage tank. The water flows from the oil treater to the corrugated plate interceptor (CPI).

Figure 87 is a flow schematic for the water treating system. The water flows from the CPI through two flotation units operating in series, and then to discharge. Platform SS198G was the only platform in this survey with two flotation units. In order for SS198G to be comparable to the rest of the platforms, the effluent from the first flotation unit is considered the platform effluent.

Skimmings from the CPI and flotation units were pumped to the oil treater on Days 1 through 4 and part of Day 10. The rest of the time the skimmings were pumped to the oil storage tank.

The water which settled out in the oil storage tank was periodically drained to the skim sump. Miscellaneous other drains discharge to skim sumps, and any oil recovered is pumped to the line with the skimmings. Drip pans under rotating equipment and the LACT unit drains to the waste oil sump which pumps into the skimmings line. The flare scrubber and the fuel gas scrubber also discharge to this line.

The flow from the oil treater to the CPI was monitored continuously as described in the subsection on flow monitoring. The flows in Figure 87 were developed using this flow meter and the estimating procedures also described in the flow monitoring subsection. The average flow rates reported in Figure 87 are divided according to where the skimmings are pumped. When the skimmings were pumped to the oil storage tank they were not recycled. Any water drained from the oil storage tank flowed to the skim sump and was then discharged.

A water treating chemical, Tretolite FR88, was added to the flotation unit influent. The addition rate varied from 0 to 4.6 dm^3/d (1.2 gpd).

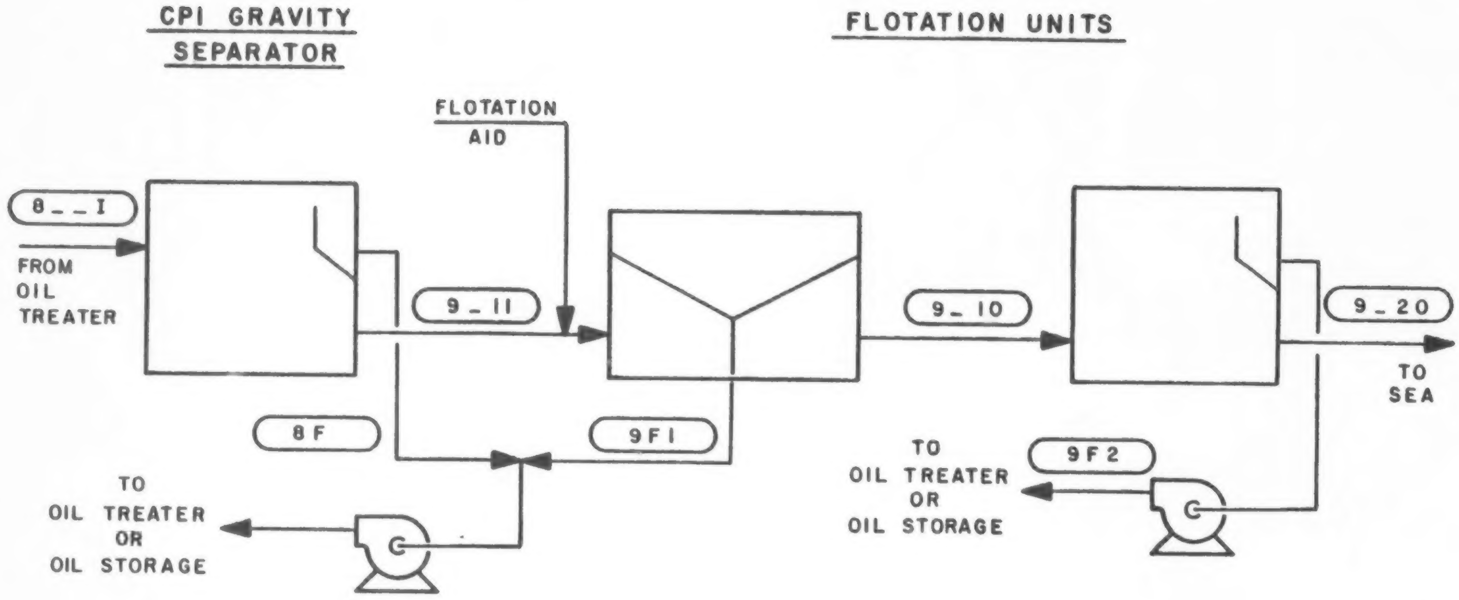
The CPI unit is a gravity separator of proprietary design supplied by Monarch Separators, Inc. Oil separates as the water flows between parallel plates spaced approximately 2 cm (0.75 in.) apart. Figure 44 is a undimensioned representational sketch of a CPI unit.

The CPI unit on SS198G is a one-pack unit. The approximate dimensions of the pack are 1 m high, 1 m wide, and 1.75 m long. Based on the manufacturer's recommended sizing procedure and the conditions prevailing on SS198G during the survey, the CPI on SS198G should accomplish the separation of 40-micron oil drops at flow rates up to 870 m^3/d (5,500 bpd). Average hydraulic loading was estimated to be 10.2 m^3/d (64 bpd), or 1.2 percent of design.

TABLE 143. SS198G VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 13-1 5A3 Low pressure 2-phase separator	 6 Oil treater, chem electric	 8 Gravity separator, CPI	 9-1 Flotation unit, hydraulic dispersed gas	 9-2 Flotation unit, hydraulic dispersed gas
Trade Name or Vessel Type	Horizontal Cylinder	Horizontal Cylinder	Monarch(1)	Tridair Model DC500	Monosep Model AG-3000
Design Parameters					
Dimensions, m, (ft)					
Diameter, O.D.	0.91(3)	2.44(8)	-	-	-
Length, S.S.	3.05(10)	4.57(15)	-	-	-
Length	-	-	-	3.20(10.5)(3)	2.59(8.5)
Width	-	-	-	1.07(3.5)(3)	1.52(5)
Height	-	-	-	-	-
Separation Surface Area, m^2, (ft^2)					
Total	-	-	-	3.42(36.8)	3.07(33)
Per Cell	-	-	-	1.14(12.3)	-
Separation Volume, m^3, (bbl)					
Total	-	-	-	2.8(18)	5.1(32)
Oil Phase	-	-	-	-	-
Water Phase	-	-	-	-	-
Number of Cells	-	-	-	3	-
Flow Rate, m^3/day, (bpd)	-	286(1,800)	870(5,500)(2)	795(5,000)	490(3,100)
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)(5)	-	-	-	700(410)	160(94)
Recycle Rate, Percent of Flow	-	-	-	450	400
Retention Time, min.	-	-	-	5	15
Average Operating Parameters					
Temperature, ^{o}C(^{o}F)	-	36.5(98)	33.4(92)	31.1(88)	-
Pressure, kPag (psig)	640(93)	440(64)	0(0)	0(0)	0(0)
Flow Rate, m^3/d (bpd)(4)	-	15.6(98)	10.2(64)	9.2(58)	8.9(56)
Flow Rate, Percent of Design	-	-	-	1.2	1.8
Overflow Rate Per Cell, (m^3/d)/m^2,(bpd/ft^2)	-	-	-	8.1(4.7)	2.9(1.7)
Recycle Rate, Percent of Flow	-	-	-	39,000	22,000
Froth Flow, Percent of Flow	-	-	-	11	3

(1) Proprietary unit with one plate pack.
(2) Based on removing 40-μm oil drops.
(3) Separation area.
(4) Effluent flow.
(5) Overflow rate is surface area divided by flow rate.


CPI GRAVITY SEPARATOR
FLOTATION UNITS
FLOTATION AID
8__I
FROM OIL TREATER
9_11
9_10
9_20
TO SEA
8F
9FI
9F2
TO OIL TREATER OR OIL STORAGE
TO OIL TREATER OR OIL STORAGE

WATER FLOW		8F	8__I	9FI	9_II	9_10	9F2	9_20
SKIMMINGS TO	m^3/d	7.2	19.6	1	12.4	11.4	0.3	11.1
OIL TREATER	bpd	45	123	6	78	72	2	70
SKIMMINGS TO	m^3/d	4	12.4	1	8.4	7.4	0.3	7.1
OIL STORAGE	bpd	25	78	6	53	47	2	45

Figure 87. SS198G water handling system flow schematic.

The first flotation unit, a Tridair (Model DC500), is a proprietary three-cell dispersed gas unit similar to the four-cell unit depicted in Figure 32. Gas for flotation is educted hydraulically. Oil separation is by skimming froth over a side weir in each section.

The design flow for the unit is 795 m^3/d (5,000 bpd). The average operating flow based on effluent flow was 9.2 m^3/d (58 bpd) or 1.2 percent of design flow. The froth flow was 1 m^3/d (6 bpd) or 11 percent of forward flow. The recycle flow was 3,590 m^3/d (22,600 bpd).

The second flotation unit, a Monosep (Model AG-3000), is a proprietary one-cell dispersed gas unit. The unit is depicted in Figure 19 and the dimensions are in Table 143. Gas for flotation is educted hydraulically. Froth is removed over a single weir at the outlet end. The recycle water flow for gas dispersion is 400 percent of the design forward flow.

The design flow for the unit is 490 m^3/d (3,100 bpd). The average operating flow rate was 8.9 m^3/d (56 bpd), based on effluent flow or 1.8 percent of design flow. The average froth flow was 0.3 m^3/d (2 bpd) or 3 percent of the forward flow.

SITE SPECIFIC TEST PROGRAM

The planned test program for brine samples was accomplished as presented in Table 144 with one exception. The ten GR-Oil tests that were to be performed at 9-1i were inadvertently taken at 8--i. The number of samples to be taken in ten days and the time the samples were to be taken each day are listed in Table 144. For this survey sample point 9-10 is considered the platform effluent, and for that reason the bulk of the tests were performed on samples from 9-10 and not 9-20.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

Particle size distribution tests were run and are reported in Section 16.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operations are reported in this subsection.

Flow Monitoring

The water flow patterns are shown in Figure 86 and Figure 87. The primary flow is the produced water from the wells. The only other significant flow is the CPI skimmings.

The flow from the oil treater to the CPI was monitored continuously with a positive-displacement type flow meter. The skimmings flows were estimated four times daily based on manufacturer's pump data on volume per stroke. The Tridair froth flow was estimated at 1 m^3/d based on the visual observation of

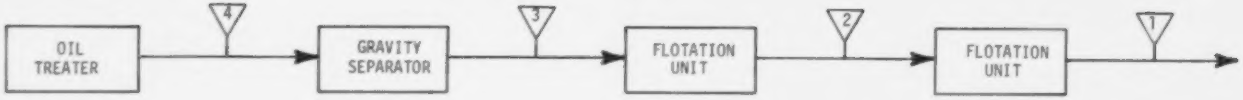


TABLE 144. SS198G TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS							
	1		2		3		4	
	9-20		9-21		9-11		8--1	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests								
Infrared Oil	20	8,13	20	8,13	20	8,13	20	8,13
Temperature	10	8	10	8	10	8	10	8
pH	-	-	10	8	-	-	-	-
Water Specific Gravity	-	-	10	8	-	-	-	-
Water Surface Tension[2]	-	-	10	8	-	-	10	8
IR-Oil W/Silica Gel	-	-	20	8,13	-	-	10	8
IR-Oil Filtered Brine	-	-	20	8,13	-	-	10	8
Susceptibility to Separation[3]	-	-	-	-	-	-	3	13
Laboratory Tests								
Gravimetric Oil	-	-	40	8,10,13,15	10	8	-	-
Suspended Solids	10	8	10	8	10	8	10	8
Ionic Analysis	-	-	1	(1)	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.							
Particle Size Distribution	3	13	-	-	3	13	3	13

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/Silica Gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/Silica Gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

the flexible paddles wiping a minimal amount of liquid over the weir and into the launder. Using this flow information a Tridair effluent and skimmings flow rate were estimated for each sample period. These flows are recorded in Table 145.

The produced water flow rate indicated in Figure 87 is less than half the rate shown in the last test of Well G5 on March 1, 1980. The produced water rate ranged from 21 bpd to 275 bpd in the seven tests of Well G5 over the previous eight months. A total of three water cuts were run on the fluid from Well G5 in an effort to explain the discrepancy between the well test data and the flow meter. These water cuts ranged from 6 to 30 percent. This information shows that the amount of water produced by Well G5 is highly variable and the flow meter information is assumed to be correct.

Well Test Data

The well test data provided by the operator are presented in Table 146. The wells are grouped according to whether the flow was to the high-pressure or low-pressure separator.

Pressure Drops Through System

Table 147 traces pressure drops from the wellhead through the system. The table includes only the well producing water.

The table shows that substantial pressure drops occur at the chokes and more minor drops from the chokes on.

Chemical Addition

Three chemicals were added by metering pumps. Chemical usage was monitored daily by noting the volume of chemical remaining in the feed pump reservoir.

A flotation aid, Tretolite FR88, was added about one meter upstream of the flotation unit. The 9-1i sample was taken at the same point. The addition rate was not uniform. An addition rate for each day is presented in Table 148.

The flotation aid chemical feedpump was operating on Days 2 and 3 but there was not a measurable change in the liquid level in the chemical reservoir. The operator adjusted the feed rate the evening of Day 3.

Samples were taken at 9-1i at 0800 and 1300. Before taking a sample at 9-1i, the injection of flotation aid chemical was stopped by closing a valve. On Day 10 the valve was already closed when the survey team went to take the 0800 sample. The valve was probably left closed after taking the 1300 sample on Day 9.

The CPI is batch treated once per month with 19 dm^3 of scale inhibitor, Tretolite SP 36. This treatment was performed on Day 7 at the beginning of the 0800 sample period. The chemical was dumped on the inlet of the CPI.

TABLE 145. SS198G MAJOR BRINE TESTS

Sample time		Gravity separator influent (8--i)						(9-ii)	Flotation unit effluent (9-10)						Flow rate	
		GR-Oil	IR-Oil	IR-Oil w/silica gel Dispersed	IR-Oil w/silica gel Soluble	Filtered brine IR-Oil	Surface tension	IR-Oil	GR-Oil	IR-Oil	IR-Oil w/silica gel Dispersed	IR-Oil w/silica gel Soluble	Filtered brine IR-Oil	Surface tension	Out	Skimmings
Day	Hour	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	186	283	224	59	83	35	127	28	30	3	27	73	67	4.6	1
01	10	-	-	-	-	-	-	-	18	-	-	-	-	-	3.8	1
01	13	-	237	-	-	-	-	135	10	30	1	29	68	-	7.7	1
01	15	-	-	-	-	-	-	-	19	-	-	-	-	-	4.9	1
02	08	208	262	190	72	83	36	114	34	50	19	31	63	63	12.3	1
02	10	-	-	-	-	-	-	-	45	-	-	-	-	-	12.3	1
02	13	-	237	-	-	-	-	118	34	53	24	29	66	-	13.5	1
02	15	-	-	-	-	-	-	-	24	-	-	-	-	-	12.9	1
03	08	215	313	211	102	125	34	127	18	34	1	33	64	64	11.6	1
03	10	-	-	-	-	-	-	-	17	-	-	-	-	-	8.8	1
03	13	-	237	-	-	-	-	110	13	34	0	34	70	-	16.3	1
03	15	-	-	-	-	-	-	-	19	-	-	-	-	-	19.5	1
04	08	299	507	406	101	84	36	203	21	42	7	35	71	65	16.4	1
04	10	-	-	-	-	-	-	-	23	-	-	-	-	-	13.2	1
04	13	-	406	-	-	-	-	253	30	47	14	33	74	-	11.8	1
04	15	-	-	-	-	-	-	-	33	-	-	-	-	-	10.6	1
05	08	170	203	127	76	76	34	114	16	32	0	32	69	69	10.1	1
05	10	-	-	-	-	-	-	-	15	-	-	-	-	-	11.3	1
05	13	-	186	-	-	-	-	89	20	31	0	31	60	-	10.4	1
05	15	-	-	-	-	-	-	-	14	-	-	-	-	-	7.0	1
06	08	180	220	131	89	80	27	144	19	30	0	30	63	67	6.2	1
06	10	-	-	-	-	-	-	-	18	-	-	-	-	-	8.9	1
06	13	-	224	-	-	-	-	106	16	31	0	31	65	-	8.3	1
06	15	-	-	-	-	-	-	-	14	-	-	-	-	-	9.4	1
07	08	145	182	114	68	81	33	110	247(B)	27	0	27	64	69	9.9	1
07	10	-	-	-	-	-	-	-	9	-	-	-	-	-	14.0	1
07	13	-	199	-	-	-	-	114	9	33	8	25	66	-	6.6	1
07	15	-	-	-	-	-	-	-	9	-	-	-	-	-	7.0	1
08	08	160	224	135	89	79	31	118	22	35	3	32	62	64	1.1	1
08	10	-	-	-	-	-	-	-	22	-	-	-	-	-	6.0	1
08	13	-	245	-	-	-	-	110	27	47	15	32	64	-	4.7	1
08	15	-	-	-	-	-	-	-	11	-	-	-	-	-	4.6	1
09	08	144	207	80	127	76	33	114	2	32	0	32	61	68	6.4	1
09	10	-	-	-	-	-	-	-	3	-	-	-	-	-	5.9	1
09	13	-	232	-	-	-	-	106	5	32	0	32	64	-	7.1	1
09	15	-	-	-	-	-	-	-	11	-	-	-	-	-	5.7	1
10	08	157	220	169	51	97	31	110	47(C)	79(C)	46(C)	33(C)	68(C)	63(C)	7.2	1
10	10	-	-	-	-	-	-	-	25	-	-	-	-	-	11.9	1
10	13	-	330	-	-	-	-	177	14	41	14	27	63	-	11.9	1
10	15	-	-	-	-	-	-	-	10	-	-	-	-	-	7.7	1
Minimum		144	182	80	51	76	27	89	2	27	0	25	60	63	1.1	-
Maximum		299	507	406	127	125	36	253	45	53	24	35	74	69	19.5	-

(B) Not included in statistical analysis. Salt crystals were observed after freon was evaporated for the test.
(C) Not included in statistical analysis. Survey team inadvertently cut off flotation chemical feed to the system.

TABLE 146. SS198G WELL TEST DATA

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig SIBHP	FTP	Choke size 1/64 in.	API gravity
Flowing to High Pressure Separator										
G4		9,668	5,400	0	0	0	2,834	1,900	21	52.0
G4D		9,602	5,700	8	0	0	2,447	1,450	25	52.0
G6D		9,768	1,720	0	0	0	2,854	1,900	13	55.0
G13D		9,785	1,100	0	0	0	2,818	1,700	10	54.0
Total (Average)		-	13,920	8	0	0	-	-	-	(53.2)
Flowing to Low Pressure Separator										
G5	KNG1	10,444	400	585	195	0	-	600	21	34.0
Combined Total		-	14,320	593	195	0	-	-	-	

TABLE 147. SS198G PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Flowing Tubing Pressure	4,140 (600)	choke, valves, pipes	3,490-3,500 (506-507)
Low Pressure Separator	640-650 (93-94)	control valve, pipes	200-210 (29-31)
Oil Treater	430-450 (62-65)	control valve, pipes	430-450 (62-65)
CPI	0		
Flotation Units	0		

TABLE 148. SS198G FLOTATION CHEMICAL ADDITION

Day	Addition rate	
	dm^3/d	ppmv(1)
01	2.6	500
02	0	0
03	0	0
04	1.1	90
05	1.9	200
06	1.9	230
07	4.6	490
08	3.0	720
09	0	0
10	3.1	320
Mean	1.8	255

(1) Based on average water flow through the flotation unit for each day.

The usage of the other chemicals is shown in Table 149.

TABLE 149. SS198G CHEMICAL ADDITION

Chemical	Addition point	Addition rate dm^3/d	ppmv
Tretolite RP2327 (Demulsifier)	Well manifold ahead of 5A2	13.2	115 (1)
Tretolite SP246 (Scale inhibitor)	Well manifold ahead of 5A2	1.7	15 (1)

(1) Based on average fluid flow through the oil treater.

Observations and Operator Reports

An effort was made to record any event that could affect effluent oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures and the survey team made their own observations.

The Monosep was put into operation on Day 2, just prior to the 1300 sample period. The unit experienced problems maintaining the proper level and was out of service for two hours on Day 3. This prevented the survey team from obtaining a 1300 sample at 9-20 on Day 3.

The Monosep skimmed a very minimal amount of froth until the afternoon of Day 3. The skimming rate then increased substantially, and overloaded the piping. The skimmings pumps could not overcome the increased line pressure. The skimmings and the other miscellaneous flows were switched to the oil storage tank the evening of Day 4. The Monosep skimmings rate then dropped until the skimmings were switched back to the oil treater on Day 10 after the 0800 sample period. The skimmings were switched to the oil storage tank after the 1300 sample period on Day 10.

Shut ins with durations of a few minutes each occurred on Days 7 and 10. Well G5 shut in three times during the morning of Day 7. The platform shut in during the 0800 sample period on Day 10.

Rain, deck washings, and vessel flushing result in flow to the skim pile. Significant flow to the skim pile causes the skim pile to pump oil into the skimmings recycle line.

Rains occurred on Days 1 and 10. The rain on Day 1 occurred before the 1500 sample period but no oil was pumped from the skim pile until after the 1500 sample. The rain on Day 10 started during the 1000 sample period and lasted until the 1300 sample period. Oil pumped from the skim pile during these times would be pumped to the oil treater.

Deck washings occurred the morning and night of Day 8. The soap was

DW-9 Rig Wash from M-Chem. Oil pumped from the skim pile during these times would have been pumped to the oil storage tank.

The Monosep was flushed out on Day 1 after the 1500 sample period. This caused the skim pile to pump oil to the oil treater.

Oil storage tank bottoms were drained to the skim sump on Days 9 and 10. On Day 9 the bottoms were drained between the 0800 and 1000 sample period. The draining was performed during the 0800 sample period on Day 10. Oil from the skim pile was pumped back to the oil storage tank during these drainings.

Accumulated liquid in the high-pressure separator was drained to the low-pressure separator on Day 2 during the 0800 sample period and on Day 8 before the 0800 sample period.

The instrument gas scrubber liquid was also drained on Day 2 and Day 8.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables, summary tables and graphs for SS198G are interspersed in this subsection. In this discussion, flotation unit effluent is the effluent from the Tridair, sample point 9-10.

Effluent Oil Content

Table 145 presents a listing of oil content test results for the major sampling points. Table 150 presents a listing of test results on the Monosep effluent (9-20). Figure 88 presents a plot of GR-Oil out of the Tridair flotation unit versus time. Figure 89 presents the same plot for IR-Oil content in and out of the Tridair. The time-indexed plots are based on two test results per day, except for the Tridair effluent GR-Oil which is based on four tests per day.

The tabulated data and time-indexed plot show that the Tridair influent is relatively uniform with only two of the 20 IR-Oil contents over 200 mg/l. The two influent values over 200 mg/l occurred on Day 4 at the same time as the two highest CPI influent values. The high oil carried through the Tridair as higher than average values. Day 4 was the last full day that skimmings were pumped back to the oil treater. The Monosep skimmings rate was also substantially higher than on previous days. The high skimmings recycle rate could have contributed to these high values.

The Tridair effluent was above average on Day 2. The flotation aid feed rate was not enough to note a change in the chemical reservoir on Day 2 or 3. The low or possibly no chemical feed on Day 2 could have contributed to the high effluent values.

The Tridair effluent was high at 0800 on Day 10 because the valve that shut off the flotation aid was closed.

The ranges of test results, not including Day 10 at 0800, are as follows:

TABLE 150. SS198G BRINE TESTS ON SECOND FLOTATION UNIT EFFLUENT (9-20)

Sample time				Suspended Solids				
Day	Hour	IR-Oil mg/l	Temperature °C	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	-	-	-	-	-	-	-
01	13	-	-	-	-	-	-	-
02	08	-	-	-	-	-	-	-
02	13	21	-	-	-	-	-	-
03	08	36	31.0	40	2	38	36	2
03	13	-	-	-	-	-	-	-
04	08	34	33.0	14	0	15	0	15
04	13	36	-	-	-	-	-	-
05	08	27	25.5	19	25	3	3	0
05	13	25	-	-	-	-	-	-
06	08	-	29.5	52	3	50	50	0
06	13	30	-	-	-	-	-	-
07	08	25	32.0	23	1	22	22	0
07	13	34	-	-	-	-	-	-
08	08	30	34.0	24	3	21	21	0
08	13	33	-	-	-	-	-	-
09	08	27	29.5	18	2	17	17	0
09	13	29	-	-	-	-	-	-
10	08	59	31.0	52	9	43	43	0
10	13	47	-	-	-	-	-	-
Minimum		21	25.5	14	0	3	0	0
Maximum		59	34.0	52	25	50	50	15

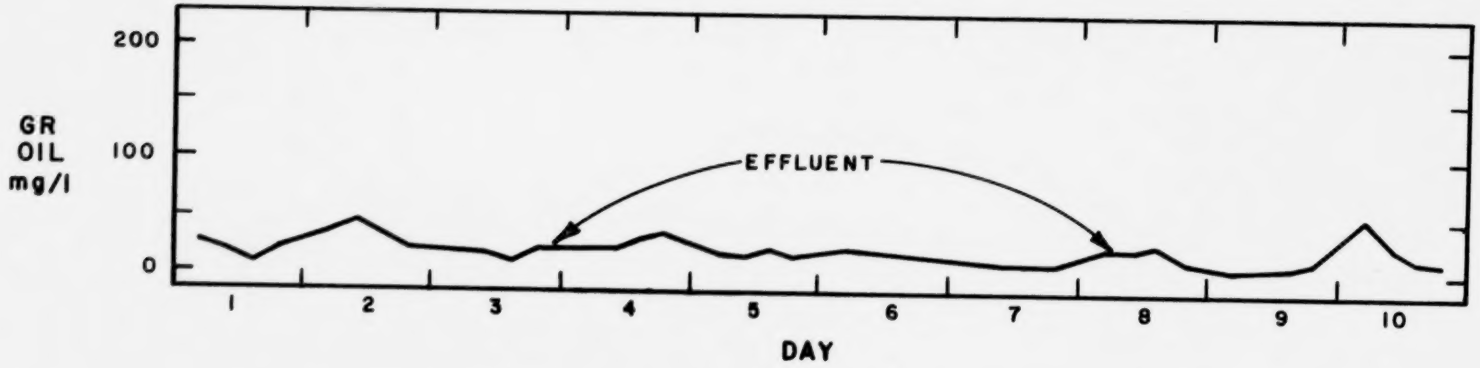


Figure 88. SS198G flotation unit performance, GR-oil vs time.

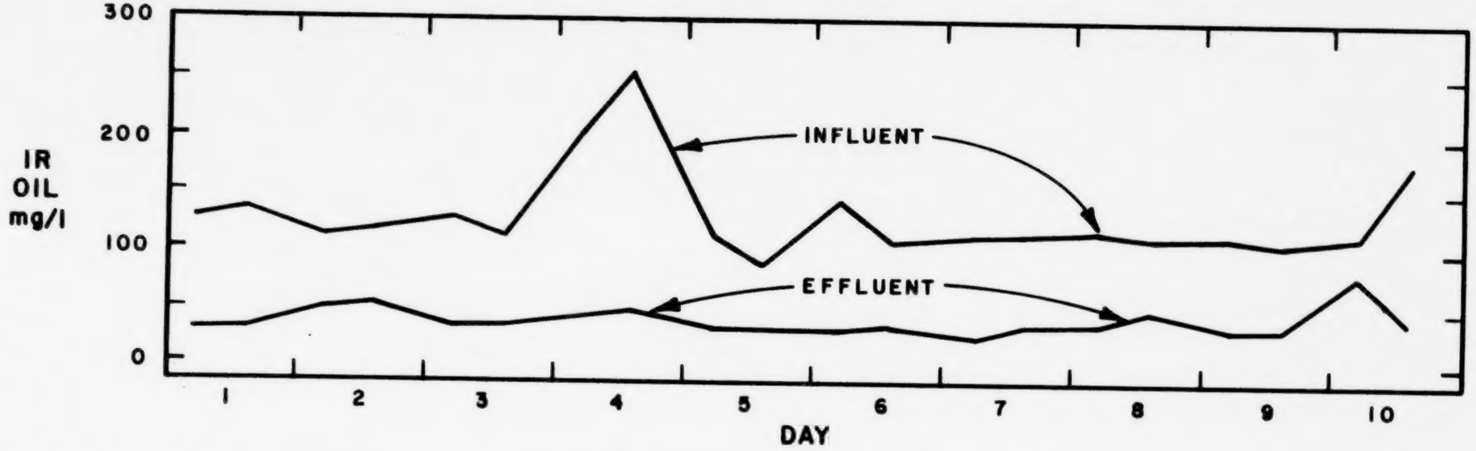


Figure 89. SS198G flotation unit performance, IR-oil vs time.

Flotation Effluent (9-10) GR-Oil - 2 to 45 mg/l,
Flotation Effluent (9-10) IR-Oil - 27 to 53 mg/l,
Flotation Influent (9-1i) IR-Oil - 89 to 253 mg/l.

Flotation unit effluent (9-10) oil content histograms for the two test methods are presented in Figure 90 and Figure 91. Figure 92 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations. Table 151 presents a summary.

The data presented in Table 151 and the histograms indicate that the mean oil content is higher by the IR-Oil test method than by the GR-Oil test method. The regression plot, Figure 92 and the correlation coefficient of 0.70 indicate only moderate correlation.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 145. A summary of these test results on the flotation unit effluent is presented in Table 152.

An average of 83 percent of the oil in the effluent was soluble oil and 17 percent was dispersed oil.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 93. Extrapolations of the linear regression lines to zero dispersed oil indicate a residual IR-Oil of 31 mg/l and a residual GR-Oil of 14 mg/l after all dispersed oil is removed. The mean soluble oil content of the flotation unit effluent was 30 mg/l.

The mean soluble oil content of the gravity separator influent was 83 mg/l, significantly higher than the mean of 30 mg/l of the flotation unit effluent.

Surface Tension

All surface tension test results are listed in Table 145. The mean surface tension of the gravity separator influent is 33 dynes/cm and of the flotation effluent (9-10) is 66 dynes/cm. The range for flotation effluent test results was from 63 to 69 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 333 - 4.5\,(\text{Surface Tension})$$
$$r = -0.68$$

Although not included in the other statistical analyses, the test result on Day 10 at 0800 when the system was upset was included in calculating the regression equation. A decrease in IR-Oil content of 4.5 mg/l is indicated for each one dyne/cm increase in surface tension.

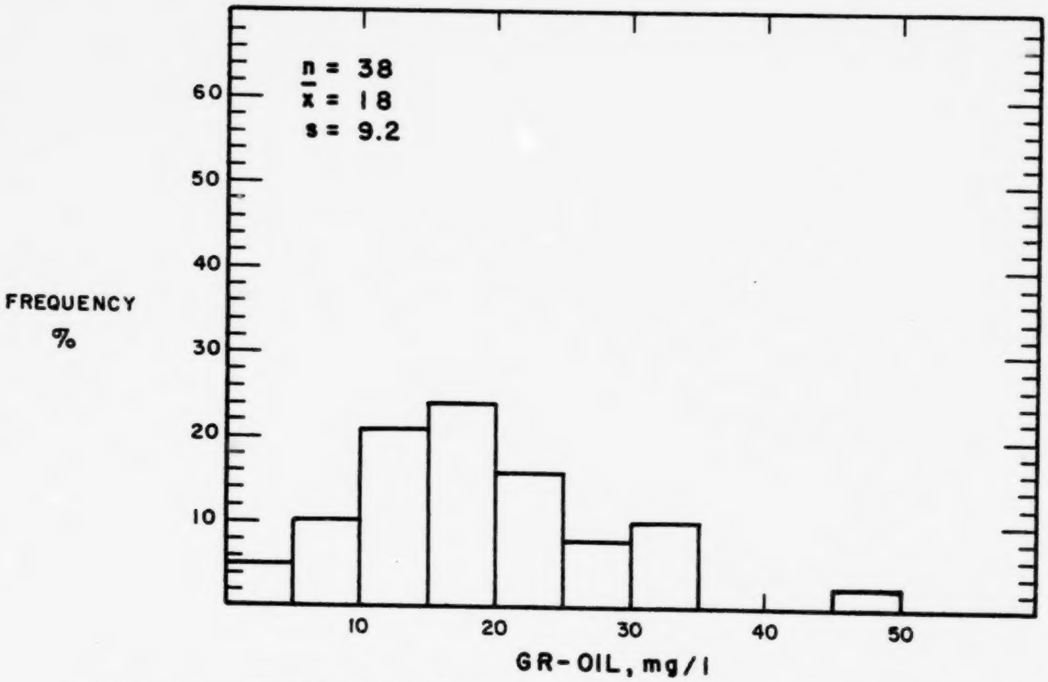


Figure 90. SS198G flotation unit effluent, GR-oil histogram.

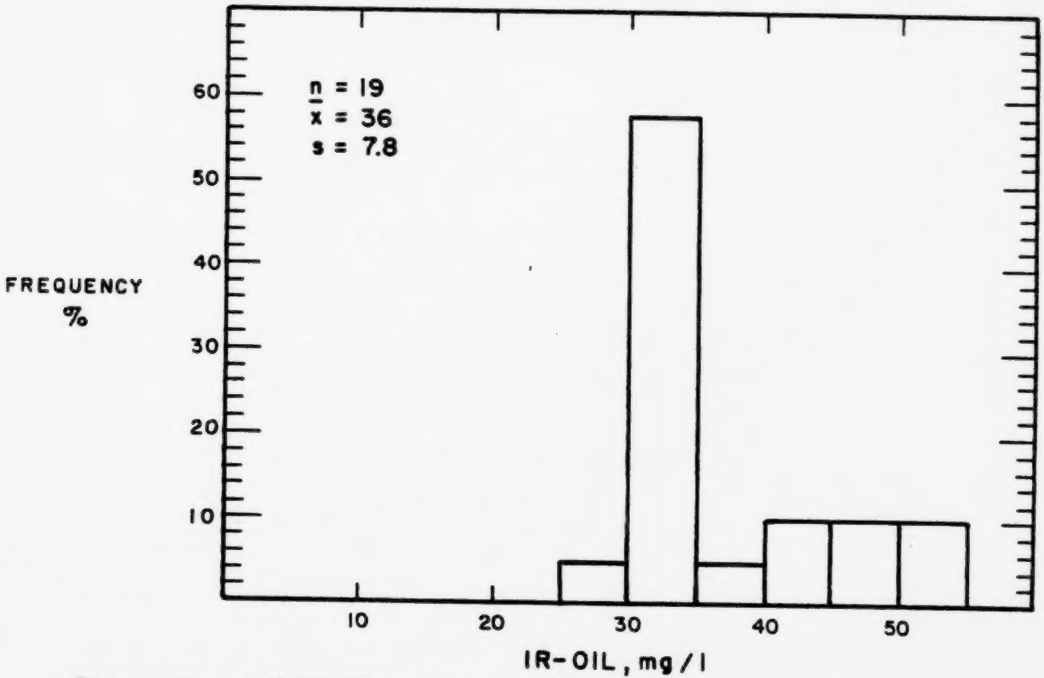


Figure 91. SS198G flotation unit effluent, IR-oil histogram.

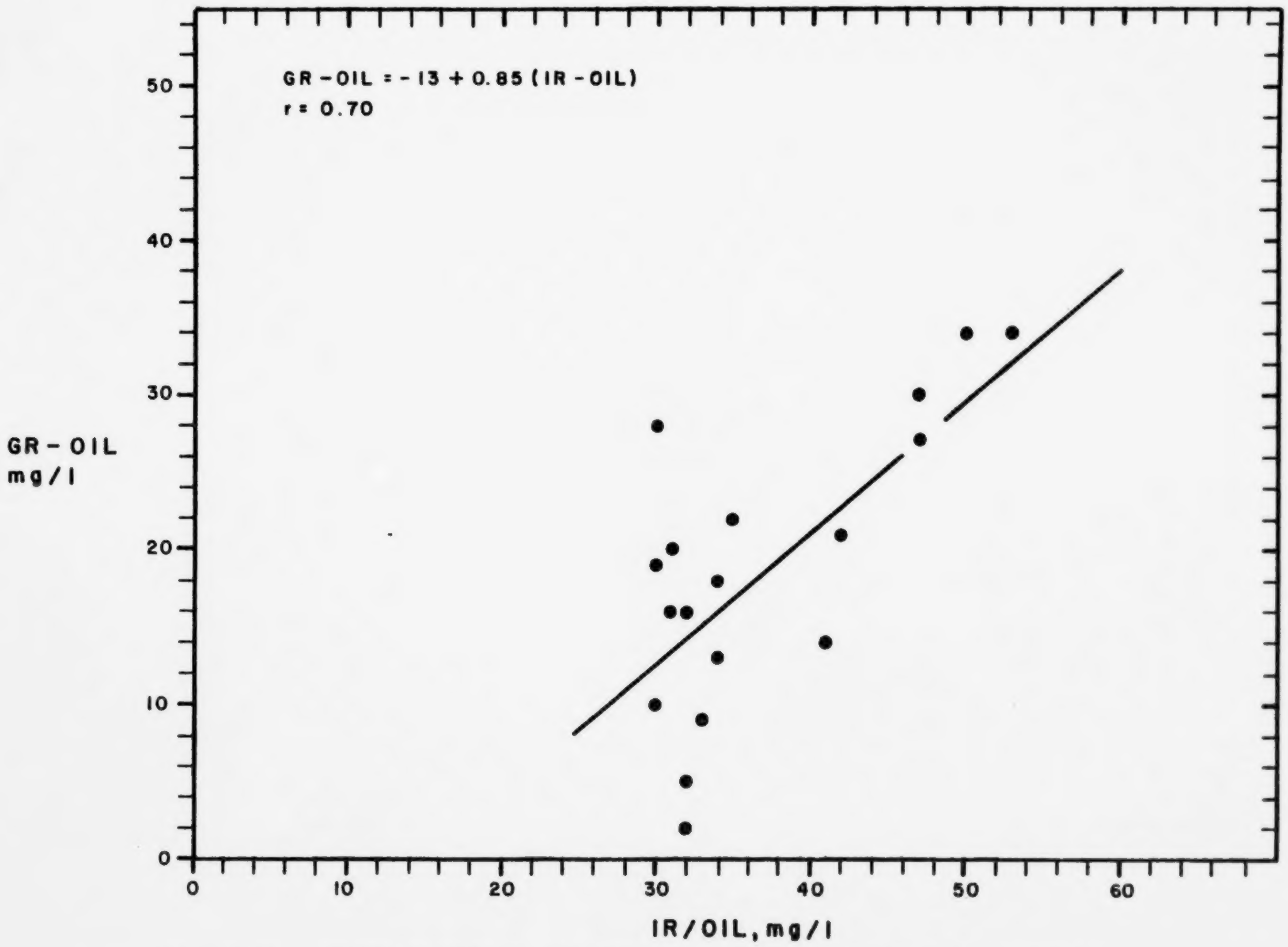


Figure 92. SS198G flotation unit effluent, infrared-gravimetric regression.

TABLE 151. SS198G FLOTATION UNIT EFFLUENT (9-10) GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-OIL
Number of tests, (n)	38	19
Mean, ($\bar{x}$), mg/l	18	36
Minimum, mg/l	2	27
Maximum, mg/l	45	53
Standard Deviation,(s),mg/l	9.2	7.8
	Paired tests	
Number, (n)	18	
Mean of Differences, ($\bar{\Delta}$), mg/l	18	
Standard Deviation, (s_Δ), mg/l	6.7	

TABLE 152. SS198G SOLUBLE OIL SUMMARY

	Flotation effluent (9-10)		
Analysis or test	Range mg/l	Mean mg/l	Proportion of total, percent
IR-Oil	27-53	36	100
Dispersed Oil	0-24	6	17
Soluble Oil	25-35	30	83

Suspended Solids

The suspended solids tests were run on the gravity separator influent, the Tridair influent and effluent, and the Monosep effluent. The data are recorded in Table 150 and Table 153 and a suspended solids summary for SS198G is presented in Table 154.

The data in Table 154 indicate that more than half of the solids were Freon soluble. There was no reduction in Freon insoluble suspended solids in the flotation unit.

Figure 94 presents time-indexed plots of Freon insoluble suspended solids in the flotation unit influent and effluent, and of flotation effluent dispersed oil. All samples were taken at the same time, 0800 each day. The plotted data do not demonstrate a distinct pattern that the dispersed oil content of the effluent is higher when suspended solids are higher in the flotation unit influent or effluent. As discussed in Section 18, the suspended solids test method may not have sufficient precision to provide meaningful

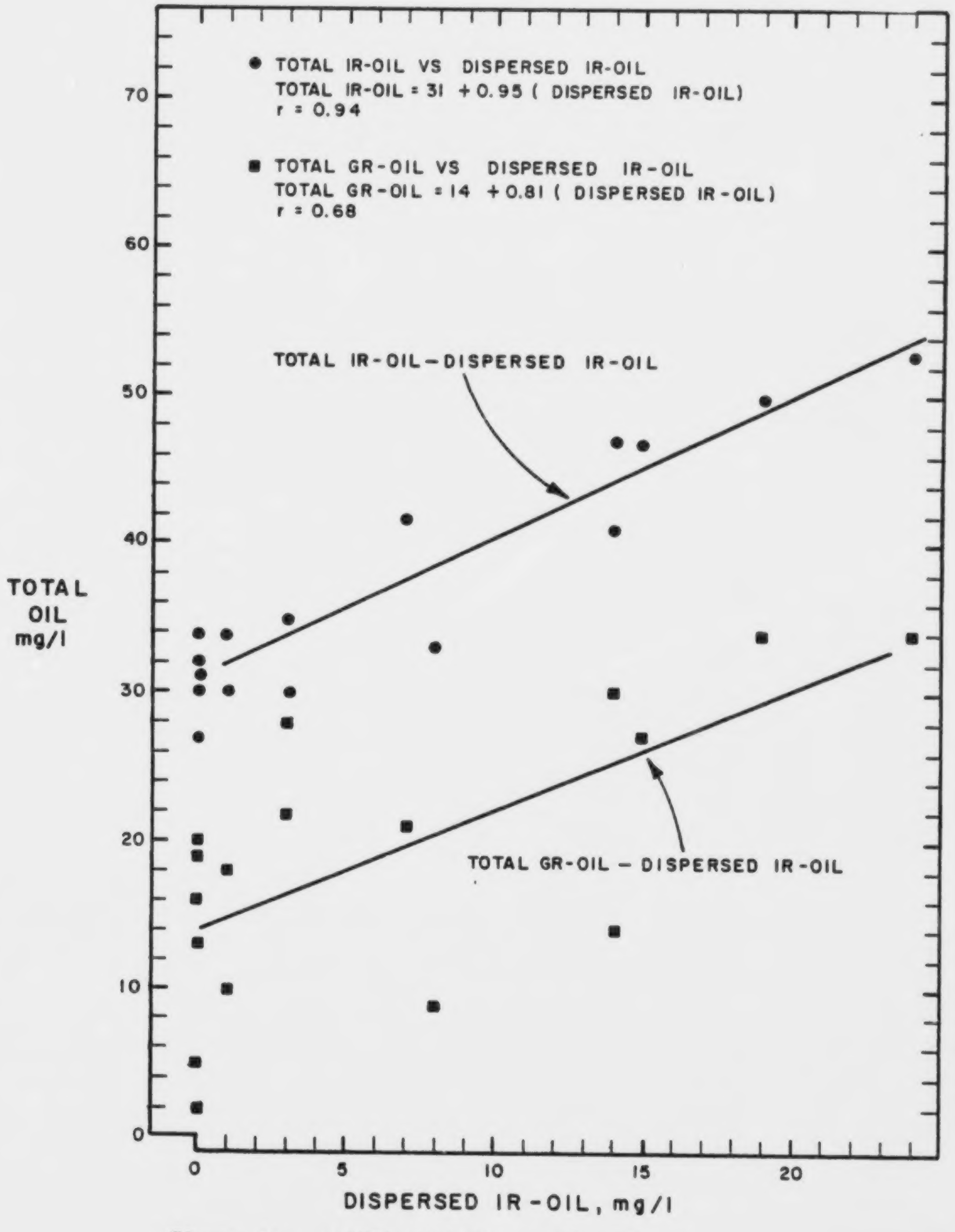


Figure 93. SS198G flotation unit effluent, total oil - dispersed oil regression.

TABLE 153. SS198G SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8--i)					Flotation unit, in (9-1i)					Flotation unit, out (9-10)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	34	35	1	1	0	25	29	0	0	0	4	6	1	1	0
02	08	27	30	1	1	0	33	34	1	1	0	19	20	2	2	0
03	08	32	34	2	2	0	33	2	32	16	16	4	5	4	4	0
04	08	35	31	4	4	0	41	38	3	3	0	6	8	4	4	0
05	08	34	29	5	5	0	35	27	8	6	2	3	0	3	3	0
06	08	31	27	4	4	0	36	40	0	0	0	20	4	16	16	0
07	08	39	40	2	2	0	15	15	1	0	0	5	3	3	3	0
08	08	17	16	1	1	0	17	19	0	0	0	3	7	1	1	0
09	08	35	28	7	7	1	48	49	0	0	0	9	1	8	0	8
10	08	59	34	24	20	5	34	38	0	0	0	31	28	2	2	0
Minimum		17	16	1	1	0	15	2	0	0	0	3	0	1	0	0
Maximum		59	40	24	20	5	48	49	32	16	16	31	28	16	16	8

TABLE 154. SS198G SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 8--i	 9-1i	 9-10
Total	34	32	10
Freon Soluble	30	29	8
Freon Insoluble	5	4	4
Acid Soluble	5	3	4
Fixed	1	2	1

results at the solids concentration in the SS198G brine.

Filtered Brine

The filtered brine IR-Oil content of SS198G effluent (9-10) was in the range of 60 to 74 mg/l with a mean of 66 mg/l. The mean effluent IR-Oil content of unfiltered brine on SS198G was 36 mg/l. The fact that the measured oil content of filtered brine was consistently higher than that for unfiltered brine indicates a bias to the high side for the filtered brine tests run on SS198G effluent.

The filtered brine mean IR-Oil content of the gravity separator influent was 86 mg/l.

Flotation Unit (Tridair) Performance

Figure 95 is a regression plot of IR-Oil in and out of the flotation unit. The slope of the linear regression line is only 0.075 indicating minor effect of influent oil on effluent oil.

The lack of the expected relationship between effluent oil and influent oil may be because of the stable influent oil (89 to 253 mg/l) and the very low hydraulic loading. The hydraulic loading was in the range of 0.1 to 2.5 percent of the design capacity of the flotation unit.

Gravity Separator Performance

The sample point for the gravity separator effluent is the same as for the flotation unit influent (9-1i). The separator influent and effluent oil content data are presented in Table 145. The separator effluent mean IR-Oil content was 130 mg/l.

The results of the susceptibility to separation tests on the gravity separator influent are presented in Table 155. The mean IR-Oil content after 120 minutes of settling was 117 mg/l. If the 117 mg/l is compared to the gravity separator effluent mean IR-Oil of 130 mg/l, the indication is that the maximum potential for a gravity separator was being approached.

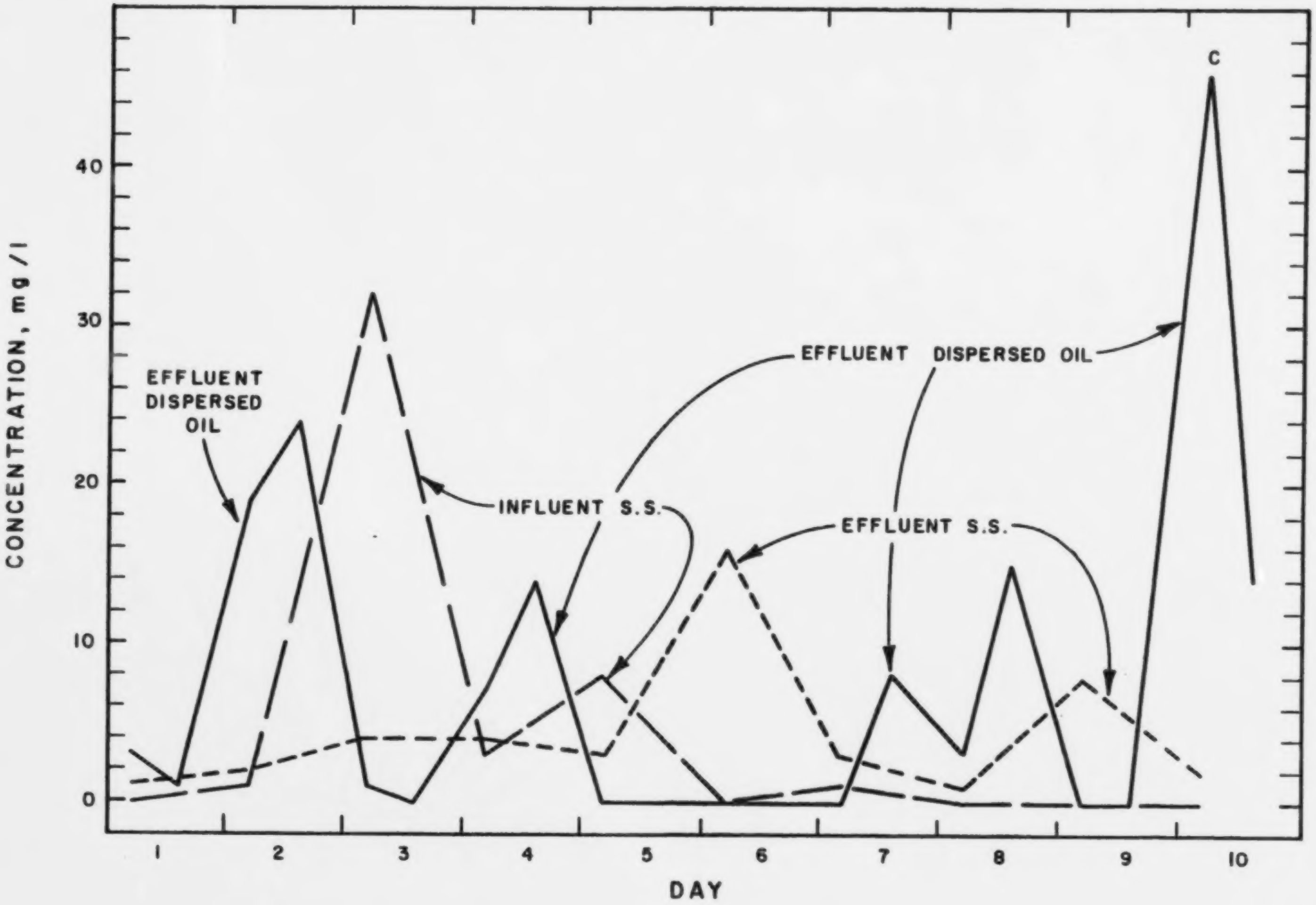


Figure 94. SS198G flotation unit Freon insoluble suspended solids.

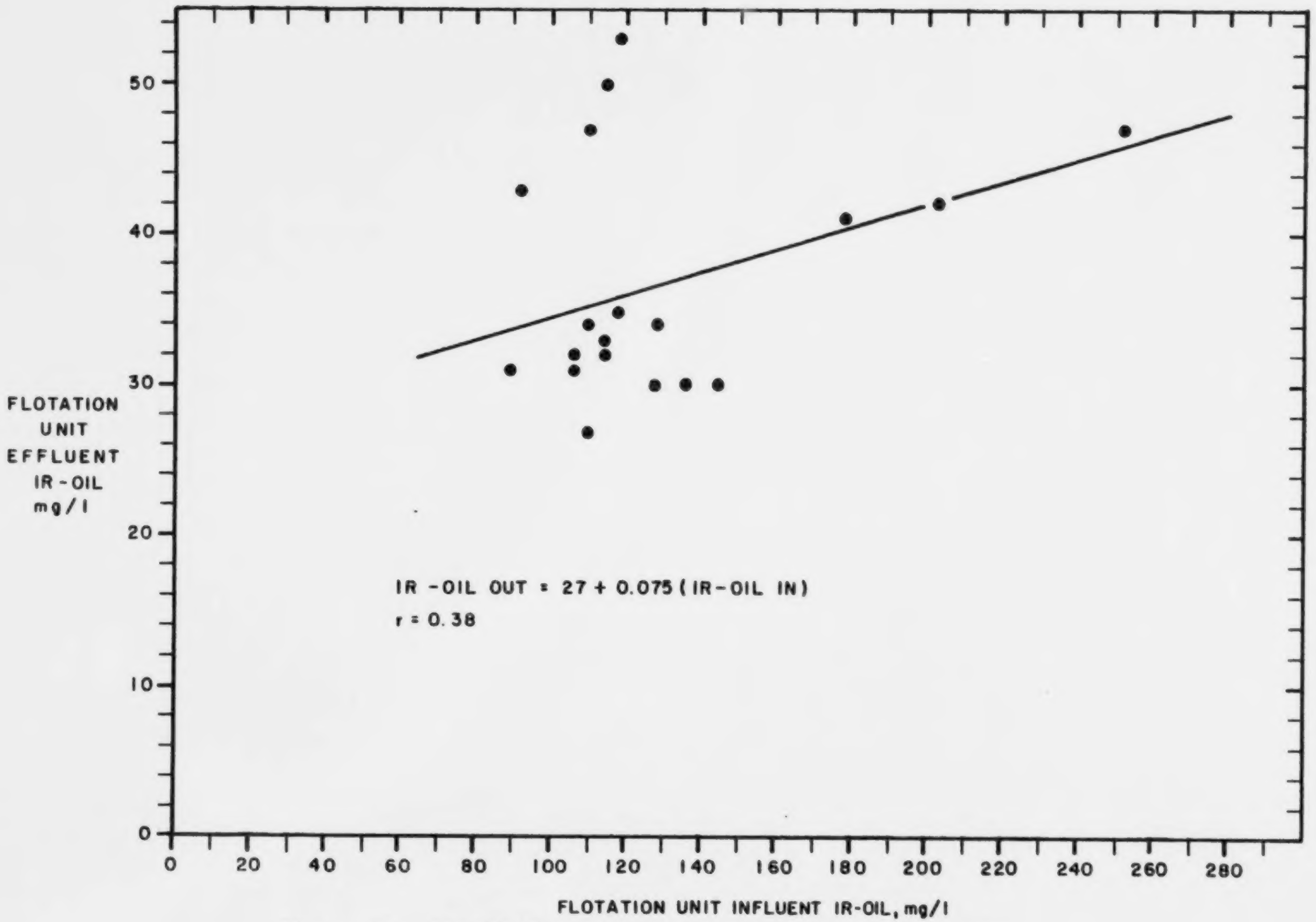


Figure 95. SS198G flotation unit in-out IR-oil regression.

TABLE 155. SS198G SUSCEPTIBILITY TO SEPARATION TESTS ON GRAVITY SEPARATOR INFLUENT

	Settling times, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 3, 1000								
IR-Oil, mg/l	258	228	237	194	173	144	101	245
IR-Oil W/Silica Gel, mg/l	173	-	135	-	-	-	25	-
Test Number 2 Day 5, 1000								
IR-Oil, mg/l	220	194	220	173	131	165	118	245
IR-Oil W/Silica Gel, mg/l	139	-	139	-	-	-	46	-
Test Number 3 Day 7, 1630								
IR-Oil, mg/l	199	194	169	182	186	148	131	186
IR-Oil W/Silica Gel, mg/l	131	-	101	-	-	-	63	-
Average								
IR-Oil, mg/l	226	205	209	183	163	152	117	225
IR-Oil W/Silica Gel, mg/l	148	-	125	-	-	-	45	-

The largest oil drop measured by the particle size test in the gravity separator effluent had a diameter of µm.

Monosep Performance

Fifteen IR-Oil tests were performed on the Monosep effluent and are presented in Table 150. The Monosep effluent IR-Oil content was in the range of 21 to 59 mg/l with a mean of 33 mg/l. The Monosep influent sample point is the same as 9-10 and the data are presented in Table 145. Monosep influent dispersed oil peaks over 10 mg/l occurred on Days 2, 4, 8, and 10. The Monosep removed the dispersed oil on Days 2, 4, and 8.

Miscellaneous Brine Tests

All other brine test results for SS198G are listed in Tables 156, 157, and 158. The results for the following tests were generally in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content. These parameters will be discussed in a later section with respect to variations between platforms.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on SS198G. These tests also are only significant with respect to comparisons between platforms.

TABLE 156. SS198G SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °C			pH	Specific gravity(1)
Day	Hour	8--i	9-1i	9-10	9-10	9-10
01	08	39.5	37.0	36.0	7.1	1.109
02	08	30.5	28.0	25.0	7.1	1.109
03	08	37.5	34.0	31.5	7.1	1.104
04	08	37.0	35.5	34.0	7.0	1.104
05	08	33.5	29.5	25.5	7.5	1.105
06	08	37.0	33.5	30.0	7.0	1.108
07	08	37.0	35.0	33.0	7.0	1.109
08	08	39.0	36.0	33.5	6.8	1.104
09	08	36.5	32.5	30.5	6.9	1.103
10	08	37.0	33.0	31.5	7.0	1.108
Mean		36.5	33.4	31.1	7.1	1.106
Minimum		30.5	28.0	25.0	6.8	1.103
Maximum		39.5	37.0	36.0	7.5	1.109

Note: Sample point identification numbers (8--i, 9-1i, 9-10) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 157. SS198G SULFATE REDUCING BACTERIA

Sample point	Bacteria per milliliter
Sump - Bottom (14--B)(1)	1,000,000
Oil Treater - Bottom (6--B)	0
Gravity Separator (CPI) - Bottom (8--B)	0
Flotation Unit - Bottom (9-1B)	0
Flotation Unit - Bottom (9-2B)	0

Sample Day and Hour: 04 at 13

(1) Water stream off bottom of skim sump on production platform.

TABLE 158. SS198G IONIC ANALYSIS FLOTATION UNIT EFFLUENT (9-10)

Constituent	Concentration, mg/l
Sodium (Na)	41,000
Potassium (K)	390
Calcium (Ca)	2,730
Magnesium (Mg)	600
Barium (Ba)	244
Chloride (Cl)	71,200
Sulfate (SO_4)	12
Alkalinity (as HCO_3)	366
Iron (Total)	6
Sulfide (as H_2S)	0.15
Total Dissolved Solids	
Summation	116,000
Gravimetric	114,000

Sample Day and Hour: 06 at 13

Crude Oil Tests

All crude oil test results are listed in Tables 159 and 160. The crude oil temperature, specific gravity, and surface tension test results all fell in a narrow range with the exception of one temperature reading.

The viscosity and boiling range distribution tests were limited in number to one and are of primary significance for comparisons between platforms. Two equilibration tests were run, each at a different oil/water ratio.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil. Between-platform comparisons will be presented in Section 17.

TABLE 159. SS198G CRUDE OIL MISCELLANEOUS TESTS(1)

Sample time Day	Sample time Hour	Temperature °C	Specific(2) gravity	Surface tension(3) dynes/cm
01	08	31.5	0.840	28
02	08	25.0	0.844	27
03	08	31.0	0.842	27
04	08	32.0	0.842	28
05	08	22.0	0.898	27
06	08	32.5	0.843	27
07	08	32.0	0.843	27
08	08	35.5	0.840	27
09	08	28.5	0.847	28
10	08	31.5	0.845	28
Mean		30.2	0.848	27
Minimum		22.0	0.840	27
Maximum		35.5	0.898	28

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
06	13	6.14	5.24

	Equilibration at 82°C Brine TDS = 116,000 mg/l	
Oil/Water Ratio	4/1	0.15/1
IR-Oil, mg/l	12	9
IR-Oil W/Silica Gel, mg/l	6	4
IR-Oil Filtered Brine, mg/l	10	8

---

(1) Samples taken from LACT unit.
(2) Specific gravity reported for temperature in table.
(3) Surface tension measured and reported at ambient temperatures from 18°C to 24°C.

TYPING GUIDE SHEET

TABLE 160. SS198G CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	500

Boiling range, °C	Percent recovered
Below - 200	48.4
200 - 250	27.2
250 - 300	17.5
300 - 350	3.2
350 - 400	1.6
400 - 450	1.2
450 - 500	0.6
Total	99.7

EPA-287 (Cin.)
(4-76)

SECTION 14

PLATFORM EI18CF

GENERAL

The ten-day testing survey was conducted on Platform EI18CF from April 1 through April 10, 1980.

A description of the production facilities, the test program, and data presentation and evaluation are presented in this section.

Three survey team members arrived at the platform on March 31 and the test equipment was set up the same day. Oil company personnel unloaded the equipment and provided living quarters, work space, sample taps, and the utilities needed to conduct the Program.

The complete testing survey was carried out without interruption by weather, operating problems, or for any other reason.

FACILITIES AND OPERATIONS

Production From Wells

Twenty-five wells were in production during the entire test program, and eleven other wells were in production for one or more days. All wells flowed or were gas lifted to either a high- or low-pressure separator.

Seventeen wells were flowing and the other nineteen wells were gas lifted. The average daily production calculated from well test data was 295 m^3/d (1,856 bpd) of oil, 2,709 m^3/d (17,037 bpd) of water, and 1,078,000 std m^3/d (38,089 Mcfd) of gas. The calculated water cut was 90 percent.

The measured oil production for the ten-day period averaged 297 m^3/d (1,869 bpd) or 0.7 percent more than the calculated production. The measured water production averaged 2,920 m^3/d (18,366 bpd) or 7.8 percent more than the calculated production.

Forty-eight percent of the oil was gas lifted, and ninety percent of the water was gas lifted.

Production Process System

The flow of oil and water through the system is shown in Figure 96.

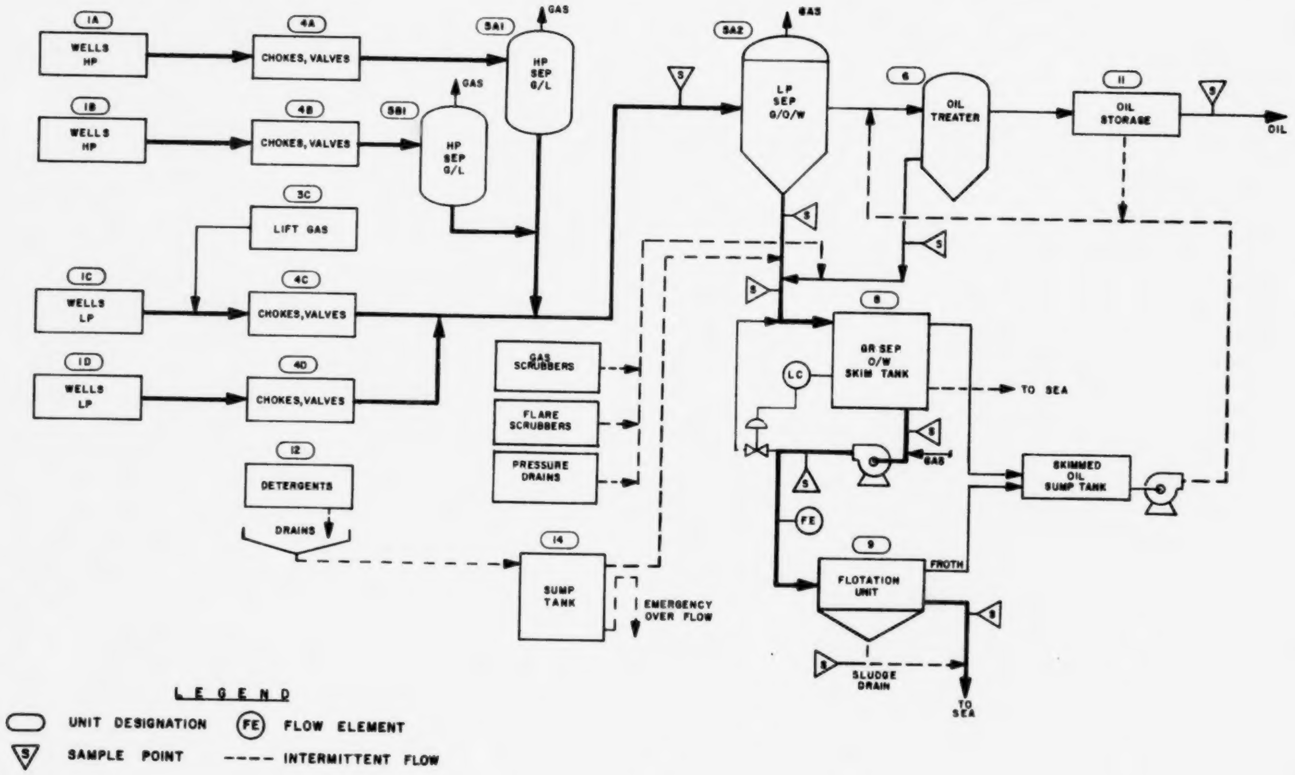

1A
WELLS HP
4A
CHOKES, VALVES
5A1
HP SEP G/L
GAS
1B
WELLS HP
4B
CHOKES, VALVES
5B1
HP SEP G/L
GAS
3C
LIFT GAS
1C
WELLS LP
4C
CHOKES, VALVES
1D
WELLS LP
4D
CHOKES, VALVES
12
DETERGENTS
DRAINS
GAS SCRUBBERS
FLARE SCRUBBERS
PRESSURE DRAINS
14
SUMP TANK
EMERGENCY OVER FLOW
S
5A2
LP SEP G/O/W
GAS
6
OIL TREATER
11
OIL STORAGE
OIL
8
GR SEP O/W SKIM TANK
TO SEA
LC
GAS
FE
9
FLOTATION UNIT
FROTH
SLUDGE DRAIN
TO SEA
SKIMMED OIL SUMP TANK
LEGEND
UNIT DESIGNATION
FE FLOW ELEMENT
SAMPLE POINT
---- INTERMITTENT FLOW

Figure 96. Flow diagram, production process system, EI18CF.

Design and operating data on major vessels are presented in Table 161. Eleven wells flowed to two high-pressure separators operating in parallel with the liquids then flowing to the low-pressure three-phase separator. Twenty-five wells flowed or were gas lifted directly to the low-pressure separator.

The oil stream from the low-pressure separator passes through an oil treater for additional brine separation. The oil is then pumped to the oil storage tank and is barged to shore about every three days. The barges hold 1,030 m^3 (6,500 bbl). No oil treating or water treating chemicals are added on EI18CF.

Figure 97 is a flow schematic for the water treating system. The primary flow is the produced water from the low-pressure separator to the skim tank which averaged 2,568 m^3/d.

Miscellaneous open drains discharge to the sump tank and the liquid is pumped with a blowcase to the skim tank. Three other blowcases receive fluid from the pressure drains, low-pressure flare scrubber and high-pressure flare scrubber. The low-pressure flare scrubber blowcase also receives fluid from all the gas scrubbers.

Water from the low-pressure separator, oil treater and blowcases flows through the skim tank and is pumped to the flotation unit and is then discharged. The flotation unit feed pump operates at a constant rate of 5,450 m^3/d (34,300 bpd). A recycle to the skim tank inlet is regulated by a skim tank level controller.

The skimmings from the skim tank and the flotation unit flow to a common sump tank and are pumped to the oil treater. The oil storage tank bottoms are pumped into the same line.

The flow to the flotation unit was monitored continuously as described in the subsection on Flow Monitoring. The flows in Figure 97 were developed using this flow meter and the estimating procedures also described in the flow metering subsection.

The gravity separator on EI18CF is a cylindrical skim tank. Figure 98 is a dimensional sketch which also shows probable flow patterns. The inlet is on the tank wall 4.27 m (14 ft) above the tank bottom. The inlet distributor is a 3.05 m (10 ft) long section of 25.4 cm (10-inch) diameter pipe with slots in the bottom. The distributor is in a horizontal position parallel to the tank wall. The outlet is on the tank wall opposite the inlet and near the tank bottom. According to the drawings, the tank has an internal oil sump with the skimming weir 5.83 m (19.1 ft) above the bottom of the tank. During normal operation the liquid level in the tank was 5.33 m (17.5 ft).

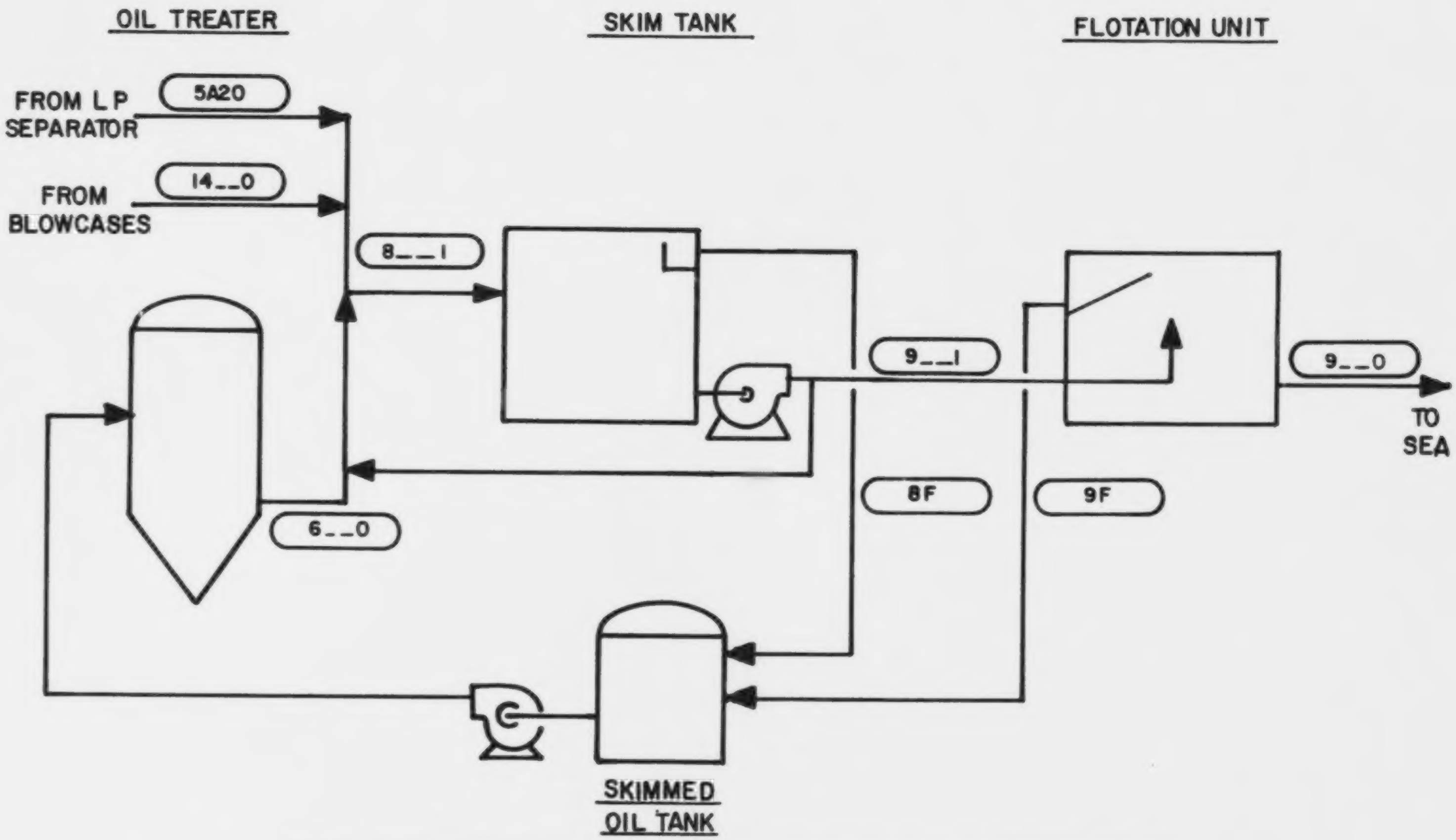
The volume below the inlet distributor is 275 m^3 (1,730 bbl). At 5,450 m^3/d (34,300 bpd) the calculated retention time is 73 minutes.

The skim tank has 21 pans for collecting and disposing of solids. The tank was equipped with an automatic pan-draining controller that was operated

TABLE 161. EI18CF VESSEL DATA SHEET

	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 14-1				
Vessel description	5A1 & 5B1 High pressure gas/liquid separator	5A2 Low pressure 3-phase separator	6 Oil treater	8 Gravity separator, skim tank	9 Flotation unit, dissolved gas
Trade Name or Vessel Type	Vertical Cylinder	Vertical Cylinder Cone-Bottom	Vertical Cylinder Cone-Bottom	Vertical Cylinder	PCE
Design Parameters					
Dimensions, m, (ft)					
Diameter, O.D.	1.22(4)	4.88(16)	3.05(10)	9.06(29.7)	7.92(26)(1)
Length, S.S.	4.57(15)	4.27(14)	9.14(30)	-	-
Length	-	-	-	-	-
Width	-	-	-	-	-
Height	-	-	-	7.35(24.1)	3.53(11.6)(1)
Separation Surface Area, m^2, (ft^2)					
Total	-	-	-	64.5(694)	49.3(531)
Per Cell	-	-	-	-	-
Separation Volume, m^3, (bbl)					
Total	-	-	-	343(2,160)	149(937)
Oil Phase	-	-	-	-	-
Water Phase	-	-	-	-	-
Number of Cells	-	-	-	-	-
Flow Rate, m^3/day, (bpd)	-	-	-	-	10,900(68,570)
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)(3)	-	-	-	-	221(129)
Recycle Rate, Percent of Flow	-	-	-	-	-
Retention Time, min.	-	-	-	-	20
Average Operating Parameters					
Temperature, $^{o}C(^{o}F)$	-	40(104)	55(131)	39.1(102)	38.2(101)
Pressure, kPag (psig)	7,310(1,060)	520(75)	310(45)	0(0)	0(0)
Flow Rate, m^3/d (bpd)(2)	-	2,568(16,152)	354(2,226)	5,450(34,300)	2,920(18,366)
Flow Rate, Percent of Design	-	-	-	-	27
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)	-	-	-	84(49)	59(35)
Recycle Rate, Percent of Flow	-	-	-	-	-
Froth Flow, Percent of Flow	-	-	-	-	0.5

(1) Separation area.
(2) Effluent flow.
(3) Overflow rate is surface area divided by flow rate.


OIL TREATER
SKIM TANK
FLOTATION UNIT
FROM LP SEPARATOR
5A20
FROM BLOWCASES
14__0
8__1
6__0
9__1
8F
9F
9__0
TO SEA
SKIMMED OIL TANK

WATER FLOW		14__0	6__0	5A20	8F	8__1	9F	9__1	9__0
	m^3/d	13	354	2568	0	7949	15	2935	2920
	bpd	82	2226	16152	0	50000	94	18460	18366

Figure 97. EI18CF water handling system flow schematic.

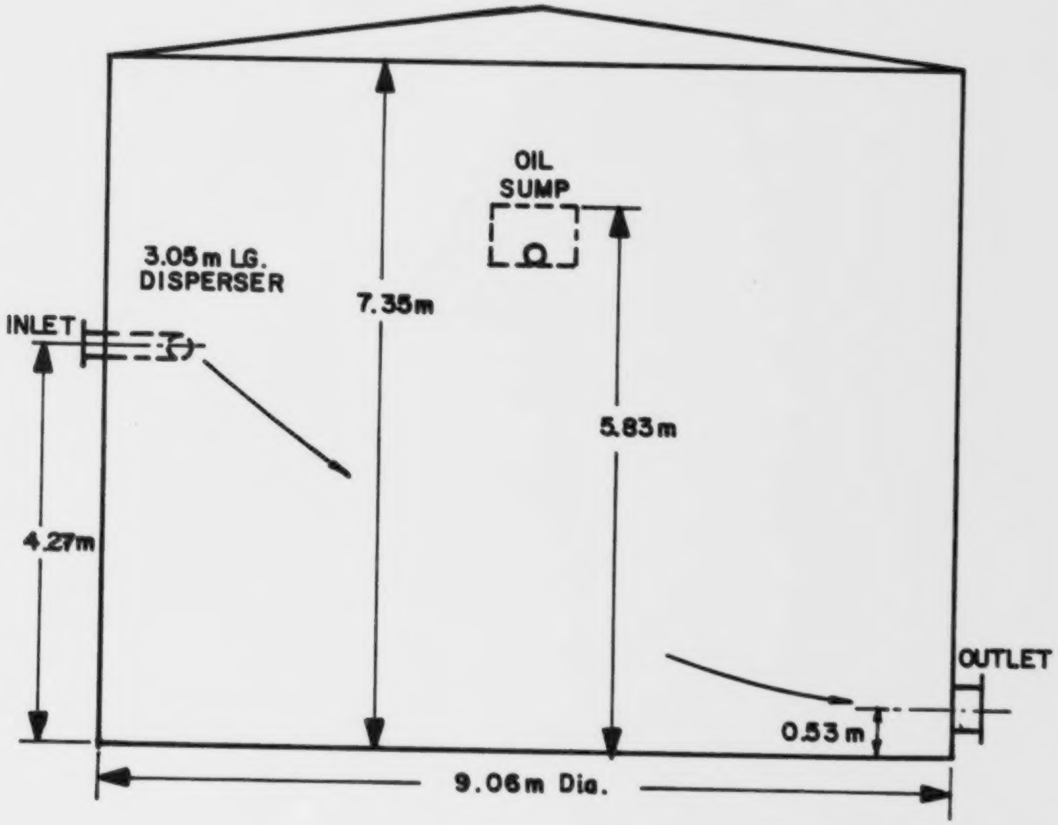


Figure 98. EI18CF skim tank.

about once per week. This dumped water and any settled solids directly to the Gulf.

The flotation unit on Platform EI18CF is a proprietary unit utilizing pressurized full flow dissolved gas flotation. Platform EI18CF is the only platform in the survey with a dissolved gas flotation unit. Figure 99 is a dimensional sketch of the unit. The gas is injected into the flotation unit feed pump suction at an average of 260 std m^3/d (9.2 Mcfd). The flow then spilts into two streams. One stream flows back to the skim tank inlet to maintain the liquid level. The other stream bypassed the retention tank which was out of service and flowed through a back-pressure valve and into the center feed well of the flotation tank. Removal of float is accomplished by a top rotating skimmer. The shaft that turns the top skimmer is driven by a bottom hydraulic sweep. The grit discharge flows to the Gulf 15 minutes out of every 105 minutes.

The design flow for this unit is 10,900 m^3/d (68,570 bpd). The average operating flow based on effluent flow was 2,920 m^3/d (18,366 bpd) or 27

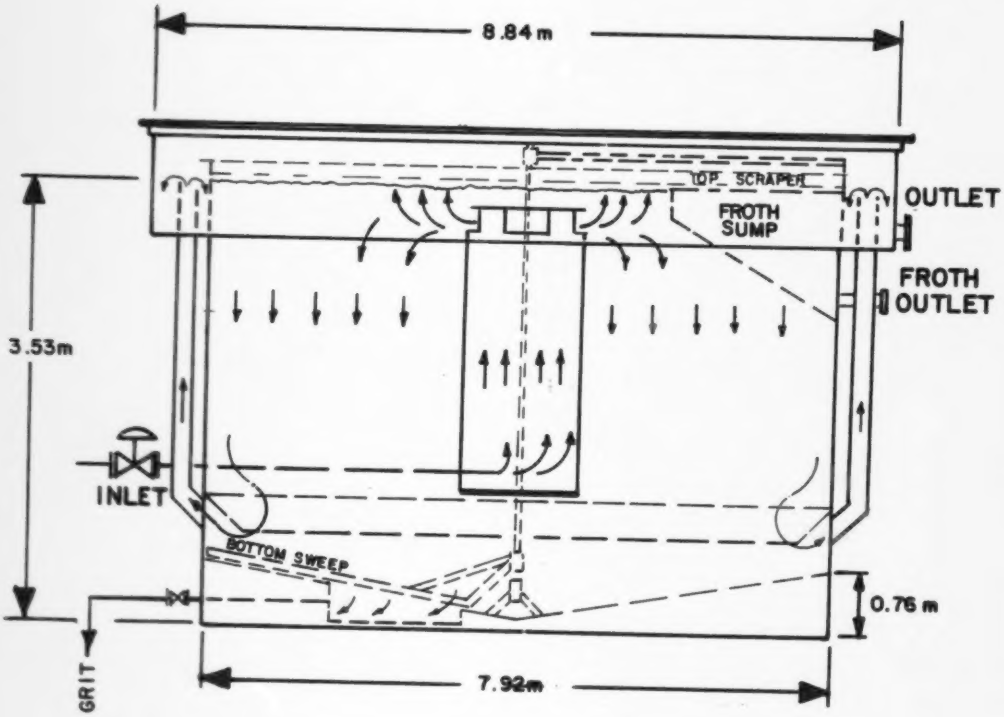


Figure 99. EI18CF flotation unit sketch.

percent of the design flow. The average overflow rate was 59 $(m^3/d)m^2$ (35 bpd/ft^2) with an average retention time of 73 minutes. Overflow rates frequently used in the design of dissolved gas flotation units range from 59 to 235 $(m^3/d)/m^2$ (1 to 4 gpm/ft^2). The froth flow averaged 15 m^3/d (94 bpd) or 0.5 percent of the effluent flow.

SITE SPECIFIC TEST PROGRAM

The planned test program for brine samples is presented in Table 162. The number of samples to be taken in ten days and the time the samples are to be taken each day are listed. The listed program was carried out with only minor variations. One variation was the addition of a sample point on the flotation unit sludge drain. The other was a change of the location of the 9--i sample point from upstream to downstream of the flotation unit feed pump.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

Particle size distribution tests were run and are reported in Section 16.

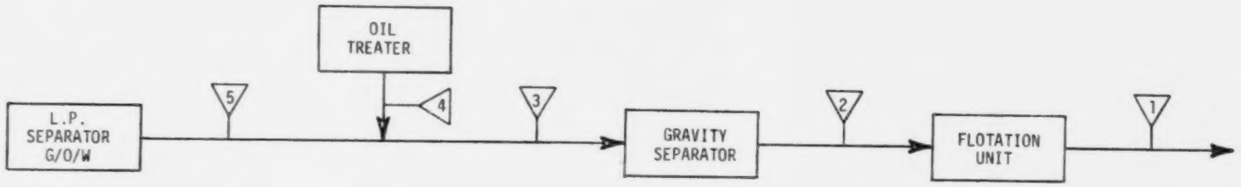


TABLE 162. EI18CF TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS									
	1		2		3		4		5	
	9--0		9--i		8--i		6--0		5A20	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests										
Infrared Oil	20	8,13	20	8,13	20	8,13	2	8	2	8
Temperature	10	8	10	8	10	8	2	8	2	8
pH	10	8	-	-	-	-	-	-	-	-
Water Specific Gravity(2)	10	8	-	-	-	-	-	-	-	-
Water Surface Tension(2)	10	8	-	-	-	-	-	-	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	10	8	-	-	-	-
IR-Oil Filtered Brine	20	8,13	-	-	10	8	-	-	-	-
Susceptibility to Separation(3)	-	-	-	-	3	13	-	-	-	-
Laboratory Tests										
Gravimetric Oil	40	8,10,13,15	10	8	-	-	-	-	-	-
Suspended Solids	10	8	10	8	10	8	-	-	-	-
Ionic Analysis	1	(1)	-	-	-	-	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.									
Particle Size Distribution(4)	3	13	3	13	3	13	-	-	-	-

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/Silica Gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/Silica Gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operations are reported in this subsection.

Flow Monitoring

The water flow patterns are shown in Figure 96 and Figure 97. The primary flow is the produced water from the wells.

The influent to the flotation unit was monitored continuously with an orifice-plate type flow meter. The flotation unit froth flow rate was calculated four times daily. The estimate was based on the rate of rise in the skimmings pump sump tank. Using this information, a flotation unit effluent and froth flow rate were calculated for each sample period. These flows are recorded in Table 163.

The skim tank skimming rate is reported as 0 in Figure 97. This is based on the fact that the oil skimming weir was 0.5 m (1.6 ft) above the oil surface during all sample periods. The skim tank liquid level was raised for five hours on Day 6 after the 1500 sample period. During that time, an estimated 60 m^3 (375 bbl) of oil was skimmed.

The average flow from the blowcases was 13 m^3/d (82 bpd). The blowcases gas was supplied by the fuel gas system. Every time a blowcase operated it was indicated on the fuel gas usage chart. Based on this information a flow rate was estimated for each sample period. The blowcase flow ranged from 0 to 80 m^3/d (504 bpd).

The distribution of water from the low-pressure separator and the oil treater is based on oil and temperature measurements at 5A20, 6--0, and 8--i on Day 6 at 0800. A balance based on this information indicated that 86 to 90 percent of the water was from the low-pressure separator.

Well Test Data

The well test data provided by the operator are listed in Table 164. The data are grouped according to whether the flow was to the high-pressure or low-pressure separator. The data for wells producing to the low-pressure separator are further subdivided according to whether the well was flowing or gas lifted. The table also shows whether a well produced all the time or for only part of the survey period.

Pressure Drops Through System

The formation pressures and the flowing tubing pressures for each well were obtained from well test data. Table 165 presents the ranges and traces the pressure drops from the producing formation through the system. The table includes only the wells producing water.

Table 165 shows that the greatest pressure drops occur from the formation to the chokes, substantial drops occur at the chokes and the high-pressure

TABLE 163. EI18CF MAJOR BRINE TESTS

Sample time		Gravity separator influent (8--i)					Flotation unit influent (9--i)		Flotation unit effluent (9--0)							
			IR-Oil w/silica gel								IR-Oil w/silica gel				Flow rate	
Day	Hour	IR-Oil	Dispersed	Soluble	Filtered brine IR-Oil	Surface tension	GR-Oil	IR-Oil	GR-Oil	IR-Oil	Dispersed	Soluble	Filtered brine IR-Oil	Surface tension	Out	Skimmings
		mg/l	mg/l	mg/l	mg/l	dynes/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	245	188	57	8	72	60	172	34	59	51	8	10	50	3,205	5
01	10	-	-	-	-	-	-	-	44	-	-	-	-	-	3,057	5
01	13	298	-	-	-	-	-	147	38	56	54	2	10	-	3,007	5
01	15	-	-	-	-	-	-	-	46	-	-	-	-	-	2,711	5
02	08	339	327	12	8	72	59	127	40	73	69	4	7	56	3,154	6
02	10	-	-	-	-	-	-	-	54	-	-	-	-	-	3,199	11
02	13	441	-	-	-	-	-	217	42	78	75	3	7	-	2,755	11
02	15	-	-	-	-	-	-	-	58	-	-	-	-	-	2,705	11
03	08	323	262	61	8	72	95	151	78	102	74	28	8	44	3,107	4
03	10	-	-	-	-	-	-	-	75	-	-	-	-	-	3,106	5
03	13	253	-	-	-	-	-	327	71	110	78	32	7	-	3,200	9
03	15	-	-	-	-	-	-	-	77	-	-	-	-	-	2,907	7
04	08	268	227	41	204	69	89	137	73	121	90	31	11	43	2,662	4
04	10	-	-	-	-	-	-	-	78	-	-	-	-	-	2,760	6
04	13	222	-	-	-	-	-	204	72	116	82	34	11	-	2,860	5
04	15	-	-	-	-	-	-	-	83	-	-	-	-	-	2,761	4
05	08	229	180	49	10	70	92	703	86	155	131	24	13	45	2,615	2
05	10	-	-	-	-	-	-	-	86	-	-	-	-	-	2,804	11
05	13	262	-	-	-	-	-	474	80	123	82	41	9	-	2,805	9
05	15	-	-	-	-	-	-	-	61	-	-	-	-	-	2,806	9
06	08	245	245	0	7	72	84	589	87	110	94	16	8	55	2,805	10
06	10	-	-	-	-	-	-	-	88	-	-	-	-	-	2,806	8
06	13	270	-	-	-	-	-	638	74	106	106	0	90	-	2,757	8
06	15	-	-	-	-	-	-	-	69	-	-	-	-	-	2,757	8
07	08	208	131	77	7	73	24	61	47	50	42	8	7	69	2,708	8
07	10	-	-	-	-	-	-	-	28	-	-	-	-	-	2,658	8
07	13	286	-	-	-	-	-	82	41	44	36	8	9	-	2,855	10
07	15	-	-	-	-	-	-	-	24	-	-	-	-	-	2,768	46
08	08	257	221	36	9	72	21	59	41	40	39	1	9	67	2,781	34
08	10	-	-	-	-	-	-	-	28	-	-	-	-	-	3,051	60
08	13	813	-	-	-	-	-	106	49	33	26	7	7	-	2,999	13
08	15	-	-	-	-	-	-	-	18	-	-	-	-	-	3,047	14
09	08	221	196	25	12	70	56	61	23	35	29	6	11	67	3,121	39
09	10	-	-	-	-	-	-	-	25	-	-	-	-	-	3,125	36
09	13	294	-	-	-	-	-	64	24	35	29	6	10	-	3,170	39
09	15	-	-	-	-	-	-	-	24	-	-	-	-	-	3,309	49
10	08	241	219	22	8	72	55	58	26	38	35	3	8	69	2,992	20
10	10	-	-	-	-	-	-	-	24	-	-	-	-	-	3,043	19
10	13	188	-	-	-	-	-	54	22	35	32	3	10	-	2,895	19
10	15	-	-	-	-	-	-	-	31	-	-	-	-	-	2,948	15
Minimum		188	131	0	7	69	21	54	18	33	26	0	7	43	2,615	2
Maximum		813	327	77	204	73	95	703	88	155	131	41	90	69	3,309	60

TABLE 164. EI18CF WELL TEST DATA

Well	Formation	TVD ft	gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig STBHP	Pressure, psig FTP	Choke size 1/64 in.	API gravity	Days of production
Flowing to High Pressure Separator											
36-22	"S$_2$" RA	10,950	2,501	26	6	0	4,776	2,750	12	48.3	All
36-30	"S$_2$" RA	11,000	4,548	56	0	0	4,750	1,400	25	45.2	All
36-31	"K" RB	8,900	860	1	488	0	-	1,200	24	46.3	All
65-11	"F$_2$" RA	9,400	4,042	37	0	0	4,060	1,400	23	47.8	All
65-12	"F$_2$" RA	8,500	5,037	48	0	0	3,940	1,550	24	51.9	All
65-15	"F$_2$" RA	8,460	3,465	29	0	0	3,755	2,450	15	51.0	All
65-19	"A" RA	6,900	5,592	77	1	0	3,070	1,700	25	52.8	All
65-26	"Q" RA	10,550	900	19	53	0	-	1,275	15	42.9	All
65-29	"Q" RA	10,600	2,888	28	0	0	4,670	1,400	19	50.0	All
67-43B	"K" RB	8,850	2,948	34	333	0	4,200	2,500	18	51.0	7(PM),8,9,10
67-45	"T$_1$" RC	11,350	4,567	51	0	0	4,411	2,500	17	46.0	All
Total (Average)		-	37,348	406	881	-	-	-	-	(48.5)	
Flowing to Low Pressure Separator											
65-5	"P" RA	10,100	785	2	60	0	-	750	14	53.6	10
65-7	"M" RA	9,400	53	40	210	0	4,060	575	12	47.0	All
65-26D	"K" RA	10,600	190	224	240	0	4,870	725	15	37.0	All
65-27	"P" RA	10,300	1,665	1	0	0	-	1,050	11	41.3	10
67-23	"O" RA SU	10,050	1,059	227	122	0	3,528	2,100	13	39.4	All
67-50D	"N" RB	9,300	114	109	409	0	-	500	19	37.7	All
Total (Average)		-	3,866	603	1,041	-	-	-	-	(42.7)	
Gas Lift to Low Pressure Separator											
36-8	"P" RB SU	10,000	9	13	0	170	3,192	90	open	39.1	All
36-10	"A" RB	6,900	127	108	297	380	2,978	100	open	39.6	All
36-15	"A" RB	6,900	40	34	223	350	2,930	90	open	39.0	1,2(AM),3-10
36-20	"O" RB	9,600	33	17	1,195	474	-	150	open	38.5	9,10
36-23	"O" RB	10,050	51	17	1,554	445	3,973	200	open	37.0	1,3-10
36-24D	"A" RB	-	31	26	1,291	380	-	150	open	37.0	1,2(AM),3,4(PM),5-10
65-2	"J" RA	8,800	49	14	232	340	3,336	200	32	37.3	1-3,9(PM),10
65-6	"K" RA	9,200	35	19	1,233	260	-	220	open	37.8	1-3,8(PM),9(PM),10
65-8	"J$_2$" RA	8,900	78	47	779	340	-	290	open	38.0	All
65-17	"M" RA	9,400	53	50	1,051	307	-	400	32	38.0	All
67-2	"N" RB	9,400	157	139	1,104	320	-	250	40	38.4	All
67-4	"N" RB	9,300	56	22	950	350	4,309	90	open	37.6	1-3
67-9	"O" RA SU	10,050	72	106	912	78	4,351	210	open	38.7	All
67-11	"O" RA SU	10,050	62	54	1,170	200	4,367	180	open	38.3	All
67-19	"K" RA	9,100	138	26	1,363	280	-	400	open	36.7	All
67-22D	"N" RC	9,700	13	29	1,188	470	4,017	170	open	30.9	All
67-26	"O" RA SU	10,050	58	61	770	55	4,348	110	open	38.4	1(0800 & 1500),2-10
67-40	"O$_4$" RA SU	10,050	33	50	503	320	3,862	150	open	38.0	All
67-42	"P" RC	9,400	155	110	1,830	312	4,380	195	open	39.2	All
Total (Average)		-	1,250	942	17,645	5,831	-	-	-	(37.8)	
Combined Total (Average)		-	42,464	1,951	19,567	5,831	-	-	-	(41.9)	

TABLE 165. EI18CF PRESSURE DROPS THROUGH SYSTEM

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Formation (SIBHP)	20,200-33,580 (2,930-4,870)	perforations, static head, pipes	9,450-29,220 (1,370-4,240)
Flowing Tubing Pressure	620-18,960 (90-2,750)	chokes, valves, pipes	103-13,960(1) (15-2,025)
High Pressure Separator	7,205-7,480 1,045-1,085)	control valve, pipes	6,685-6,960 (970-1,010)
Low Pressure Separator	470-565 (68-82)	control valve, pipes	210-565(2) (30-82)
Oil Treater	275-320 (40-46)	control valve, pipes	275-320 (40-46)
Skim Tank	0		

(1) Minimum and maximum pressure drops are to the low-pressure separator.
(2) The minimum pressure drop is to the oil treater and the maximum is to the skim tank.

separator control valve, and more minor drops from the low-pressure separator on.

Chemical Addition

No oil treating or water treating chemicals were added on EI18CF. Methanol is added at the high-pressure well heads to prevent hydrate formation. Methanol was injected at a rate of 115 dm^3/d (30 gpd). The methanol flows with the gas and fluid to EI18CF for processing.

Bench scale studies were conducted by the operator to determine if chemical addition would improve oil separation in the flotation unit. Chemicals from six companies were evaluated over a two-year period. Significant improvement in oil separation was not obtained.

Observations and Operator Reports

An effort was made to record any event that could affect effluent oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures and the survey team made their own observations.

An Eposand treatment to consolidate sand was performed on Well 65-18 just prior to the start of the survey. The well was opened up on Day 1 after the 1000 sample period. A total of 3.7 m^3 (23 bbl) of treatment fluid flowed from the well before it was shut in after the 1500 sample period.

The skim tank solids-collecting pans were drained from Day 4 after the 1500 sample period to Day 5 just before the 0800 sample period.

The skim tank effluent IR-Oil was higher than the influent on Days 5 and 6. The tank was operated with a liquid level of 5.33 m (17.5 ft). The tank drawings show the oil skimming weir 0.5 m (1.6 ft) higher at 5.83 m (19.1 ft).

On Day 6 after the 1500 sample period, the flow from the skim tank to the flotation unit was stopped. This forced the skim tank to discharge through a water leg to the Gulf and raised the skim tank liquid level high enough to skim oil. As the liquid level rose in the tank, the oil-water interface became visible in the sight glass. The oil thickness was estimated to be 0.9 m (3 ft). With the normal operating surface at 5.33 m, a 0.9 m thick oil layer would bring the oil-water interface down to 4.4 m. This is close to the inlet level of 4.27 m. This closeness of the oil level to the inlet may have resulted in the inlet flow sweeping oil that had been previously separated out of the tank. This may have caused the higher oil content tests on Day 5 and Day 6. The flow was returned to the flotation unit at about 2000.

After the first five days of the survey, the 9--i sample point was moved from upstream to downstream of the flotation unit feed pump. The upstream sample was taken from a horizontal 2.5 cm (1-inch) diameter pipe placed inside a horizontal 45.7 cm (18-inch) diameter pipe. The feed pump suction was taken from the larger pipe. The open end of the 2.5 cm pipe was upstream of the pump suction. The downstream sample was taken from the side of a vertical 10 cm (4-inch) diameter pipe immediately downstream of the pump. The change was made to ensure that the turbulence was sufficient to provide a representative sample.

The rate of gas injected into the feed pump suction was increased on Day 8 after the 0800 sample period. The rate was increased from 250 to 280 std m^3/d (9 to 10 Mcfd).

The peak blowcase flow occurred on the afternoon of Day 2 and the first three sample periods of Day 3. The flow was water that had been produced for injection and had carried over with the lift gas to the compressor suction scrubber. The carryover was due to overloading the injection water separator.

Rains and deck washings result in flow to the sump tank and the fluid is pumped to the skim tank. Rains occurred the night before Day 2, the morning of Day 2, and the morning of Day 8. Deck washings occurred on Day 9 after the 1500 sample period, using 50 to 75 dm^3 of Shell degreaser, thereby affecting the contents of the sump.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables, summary tables and graphs for EI18CF are interspersed in the text of this subsection.

Table 163 presents a listing of oil content test results for the major sampling points. Figure 100 presents a plot of GR-Oil in and out of the flotation unit versus time. Figure 101 presents the same plot for IR-Oil content. The IR-Oil time-indexed plot is based on two test results per day. The GR-Oil time-indexed plot is based on one influent and four effluent test results per day.

The tabulated data and time-indexed plot show that the flotation unit influent IR-Oil is highly variable. The influent IR-Oil has an upward trend the first six days with all values over 125 mg/l and a maximum of 703 mg/l. The last four days the influent IR-Oil is relatively uniform ranging from 54 to 106 mg/l. The skim tank oil was skimmed the evening of Day 6. The skimming stopped the increase in oil content through the skim tank and lowered the oil concentrations in the flotation unit influent. The flotation unit influent GR-Oil is relatively uniform for the entire test period, ranging from 21 to 95 mg/l.

The ranges of test results are as follows:

Flotation Effluent GR-Oil - 18 to 88 mg/l,
Flotation Effluent IR-Oil - 33 to 155 mg/l,
Flotation Influent GR-Oil - 21 to 95 mg/l,
Flotation Influent IR-Oil - 54 to 703 mg/l.

Flotation unit effluent oil content histograms for the two test methods are presented in Figure 102 and Figure 103. Figure 104 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Table 166 presents a summary comparison of test results by the two methods.

The data presented in Table 166 and the histograms indicate that the mean oil content is higher by the IR-Oil test method than by the GR-Oil test method. The regression plot and the correlation coefficient of 0.91 shown in Figure 104 indicate a significant relationship between results by the two test methods. The standard deviation of 20 mg/l for differences in paired tests indicates that there is not a uniform difference.

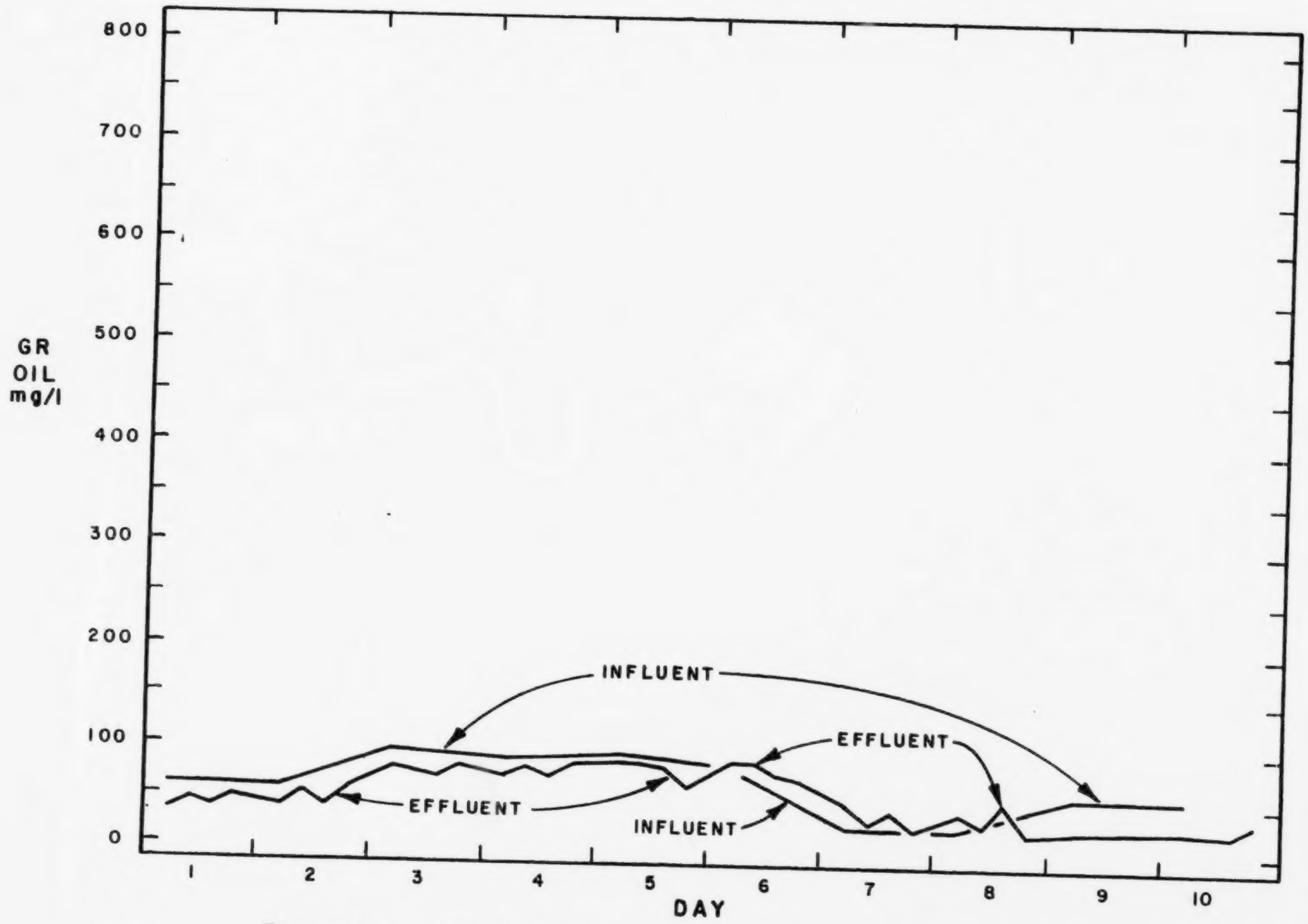


Figure 100. EI18CF flotation unit performance, GR-oil vs time.

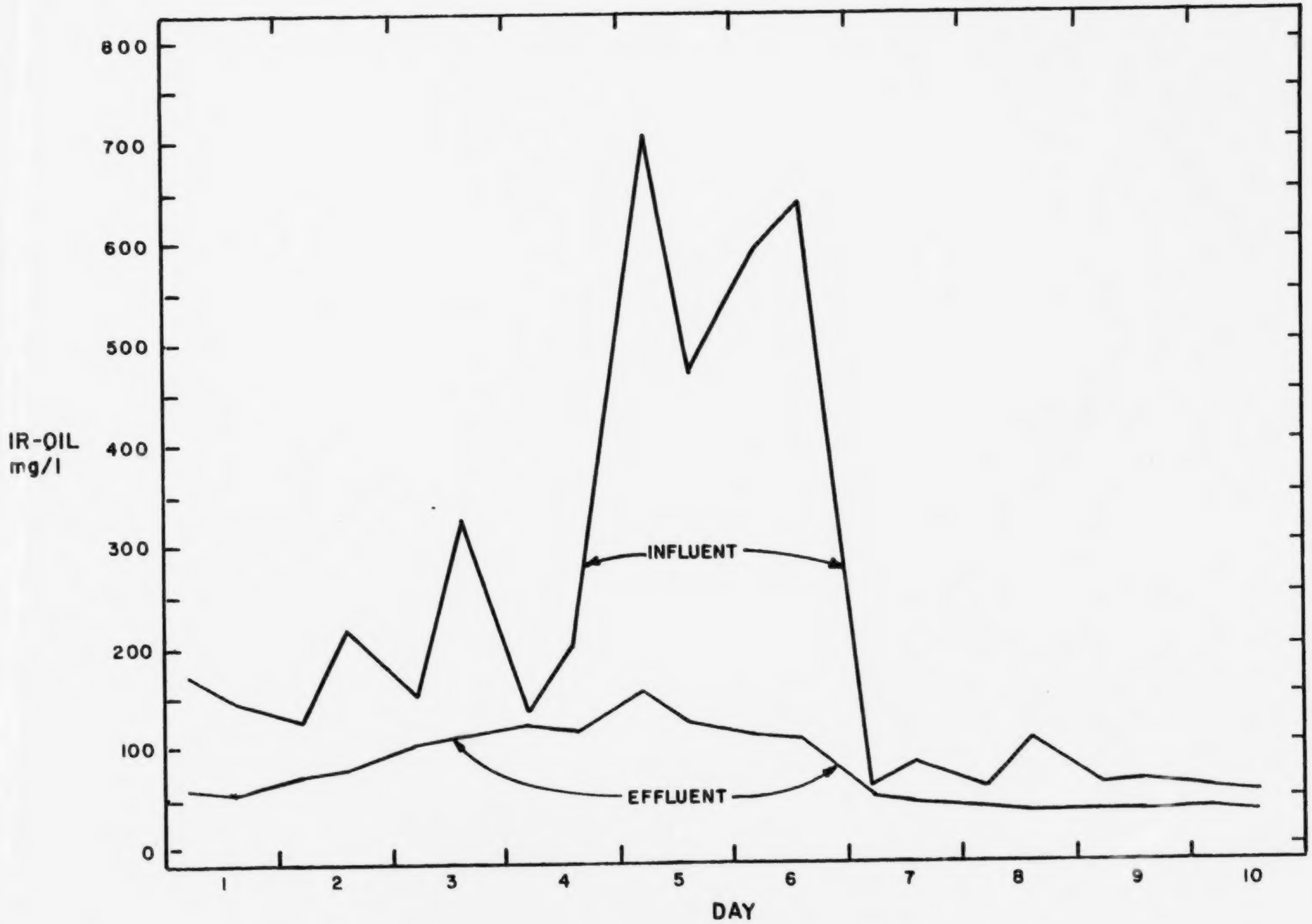


Figure 101. EI18CF flotation unit performance, IR-oil vs time.

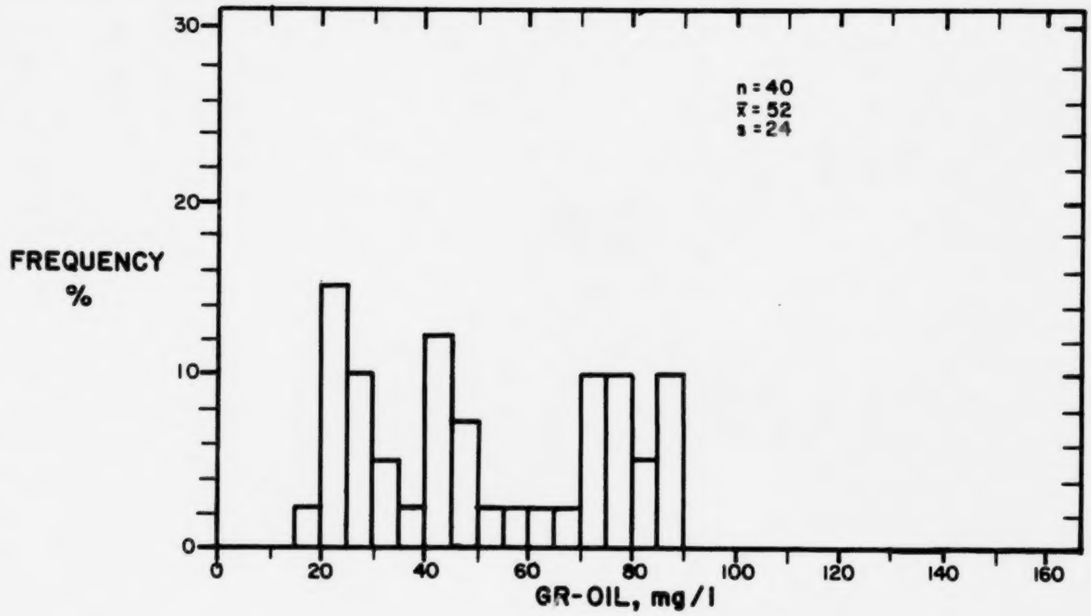


Figure 102. EI18CF flotation unit effluent, GR-oil histogram.

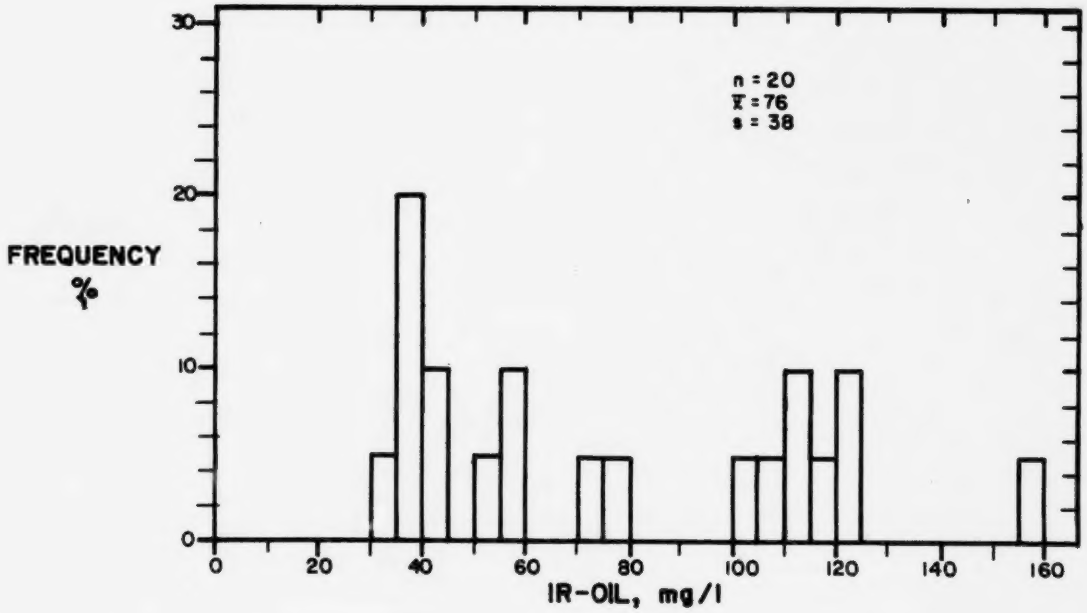


Figure 103. EI18CF flotation unit effluent, IR-oil histogram.

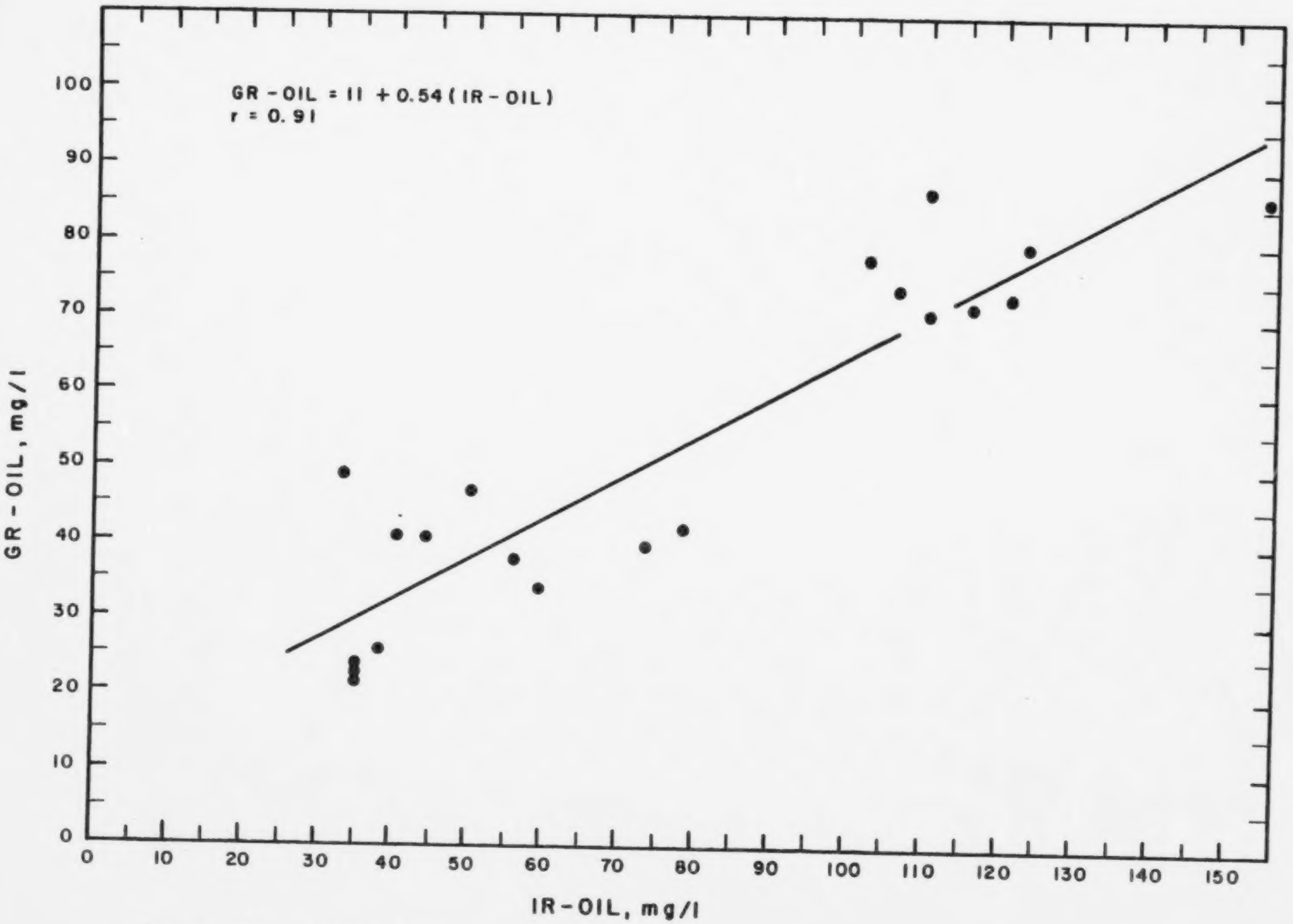


Figure 104. EI18CF flotation unit effluent, infrared-gravimetric regression.

TABLE 166. EI18CF FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	40	20
Mean, $(\bar{x})$, mg/l	52	76
Minimum, mg/l	18	33
Maximum, mg/l	88	155
Standard Deviation,(s), mg/l	24	38
	Paired tests	
Number, (n)	20	
Mean of Differences, $(\bar{\Delta})$, mg/l	24	
Standard Deviation, (s_{Δ}), mg/l	20	

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 163. A summary of these test results on the flotation unit effluent is presented in Table 167.

TABLE 167. EI18CF SOLUBLE OIL SUMMARY

	Flotaton effluent		
Analysis or test	Range mg/l	mean mg/l	Proportion of total, percent
IR-Oil	33-155	76	100
Dispersed Oil	26-131	63	83
Soluble Oil	0-41	13	17

An average of 17 percent of the oil in the effluent was soluble oil and 83 percent was dispersed oil.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 105. Extrapolations of the linear regression lines to zero dispersed oil indicate a residual IR-Oil of -1.5 mg/l and a residual GR-Oil of 12 mg/l after all dispersed oil is removed. The mean soluble oil content of the flotation unit effluent was 13 mg/l.

On Days 1, 2, and 7 through 10, flotation unit effluent IR-Oil was less than 100 mg/l, ranging from 33 to 78 mg/l. The effluent soluble oil for the days when the effluent was less than 100 mg/l ranged from 1 to 8 mg/l with a mean of 5 mg/l.

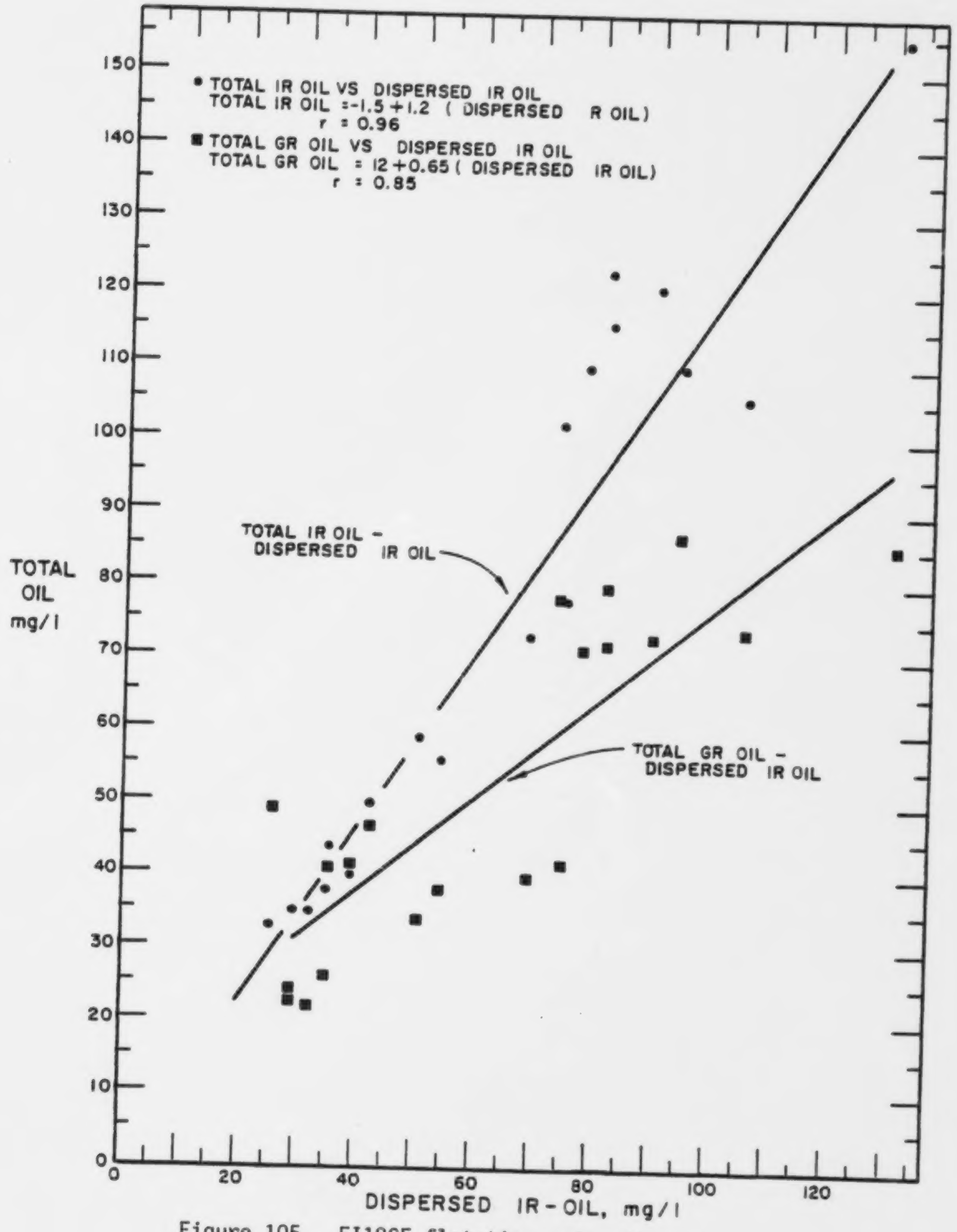


Figure 105. EI18CF flotation unit effluent, total oil - dispersed oil regression.

The mean soluble oil content of the skim tank influent was 38 mg/l, significantly higher than the mean of 13 mg/l of the flotation unit effluent.

Surface Tension

All surface tension test results are listed in Table 163. The mean surface tension of the skim tank influent is 71 dynes/cm and of the flotation effluent is 57 dynes/cm. The range for flotation effluent test results was from 43 to 69 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 261 - 3.2\,(\text{Surface Tension})$$
$$r = -0.84$$

A decrease in IR-Oil content of 3.2 mg/l is indicated for each one dyne/cm increase in surface tension. The correlation between low surface tension and high oil content is significant.

Suspended Solids

The suspended solids tests were run on the skim tank influent, and the flotation unit influent and effluent. The data are recorded in Table 168 and a suspended solids summary is presented in Table 169.

The data in Table 169 indicate that all of the solids were Freon soluble.

The suspended solids were consistent at all three sample points. The difference between maximum and minimum was 15 mg/l at 8--i, 16 mg/l at 9--i, and 14 mg/l at 9--0.

Filtered Brine

The filtered brine IR-Oil content of the EI18CF effluent was in the range of 7 to 90 mg/l with a mean of 13 mg/l. Without the 90 mg/l value, the range is 7 to 13 mg/l with a mean of 9 mg/l.

The filtered brine IR-Oil of the skim tank influent was in the range of 7 to 204 mg/l, with a mean of 28 mg/l. Without the 204 mg/l value, the range is 7 to 12 mg/l with a mean of 9 mg/l.

Flotation Unit Performance

Figure 106 is a regression plot of IR-Oil in and out of the flotation unit. The slope of the linear regression line is 0.14 and the correlation coefficient is 0.79 indicating a significant effect of influent oil on effluent oil.

Figure 107 is a regression plot of flotation unit effluent IR-Oil content and percent hydraulic loading. The slope of the linear regression line is -9, indicating a negative relationship between hydraulic loading and effluent oil. The lack of the expected positive relationship between effluent oil and hydraulic loading may be because of the moderately low and uniform

TABLE 168. EI18CF SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8--i)					Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	23	23	0	0	0	25	25	0	0	0	24	24	0	0	0
02	08	16	16	0	0	0	27	27	0	0	0	28	28	0	0	0
03	08	23	23	0	0	0	22	22	0	0	0	21	21	0	0	0
04	08	26	26	0	0	0	11	11	0	0	0	26	26	0	0	0
05	08	30	30	0	0	0	25	25	0	0	0	32	32	0	0	0
06	08	31	31	0	0	0	27	27	0	0	0	28	28	0	0	0
07	08	19	19	0	0	0	17	17	0	0	0	28	28	0	0	0
08	08	26	26	0	0	0	17	17	0	0	0	22	22	0	0	0
09	08	26	26	0	0	0	15	15	0	0	0	18	18	0	0	0
10	08	26	26	0	3	0	16	16	0	0	0	18	18	0	0	0
Minimum		16	16	0	0	0	11	11	0	0	0	18	18	0	0	0
Maximum		31	31	0	3	0	27	27	0	0	0	32	32	0	0	0

TABLE 169. EI18CF SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 8--i	 9--i	 9--0
Total	25	20	25
Freon Soluble	25	20	25
Freon Insoluble	0	0	0
Acid Soluble	0	0	0
Fixed	0	0	0

hydraulic loading. The hydraulic loading was in the range of 24 to 30 percent of the design capacity of the flotation unit.

The flotation unit sludge drain bypasses the final effluent sample point and flows to the Gulf. Five IR-Oil tests were performed on the sludge drain stream to compare the oil content of the sludge drain and the final effluent. The comparison is presented in Table 170. The means are essentially the same.

Gravity Separator Performance

The sample point for the skim tank effluent is the same as for the flotation unit influent (9--i). The skim tank influent and effluent oil content data are presented in Table 171 and Table 163. The skim tank effluent mean IR-Oil content was 222 mg/l.

The results of the susceptibility to separation tests on the skim tank influent are presented in Table 172. The mean IR-Oil content after 30 minutes of settling was 68 mg/l. If the 68 mg/l is compared to the skim tank effluent mean IR-Oil of 222 mg/l, it indicates that additional oil could be removed by static settling.

The largest oil drop detected by the particle size test in the skim tank effluent had a diameter of 97 μm.

The IR-Oil test results in and out of the skim tank and up and downstream of the pump are presented in Table 171. As discussed in the Observations subsection, the oil content was higher out of than into the skim tank on Day 3 at 1300 and Days 5 and 6.

Miscellaneous Brine Tests

All other brine test results for EI18CF are listed in Tables 173, 174, 175 and 176. The results for the following tests were generally in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content. These parameters will be discussed in a later section with respect to variations between platforms.

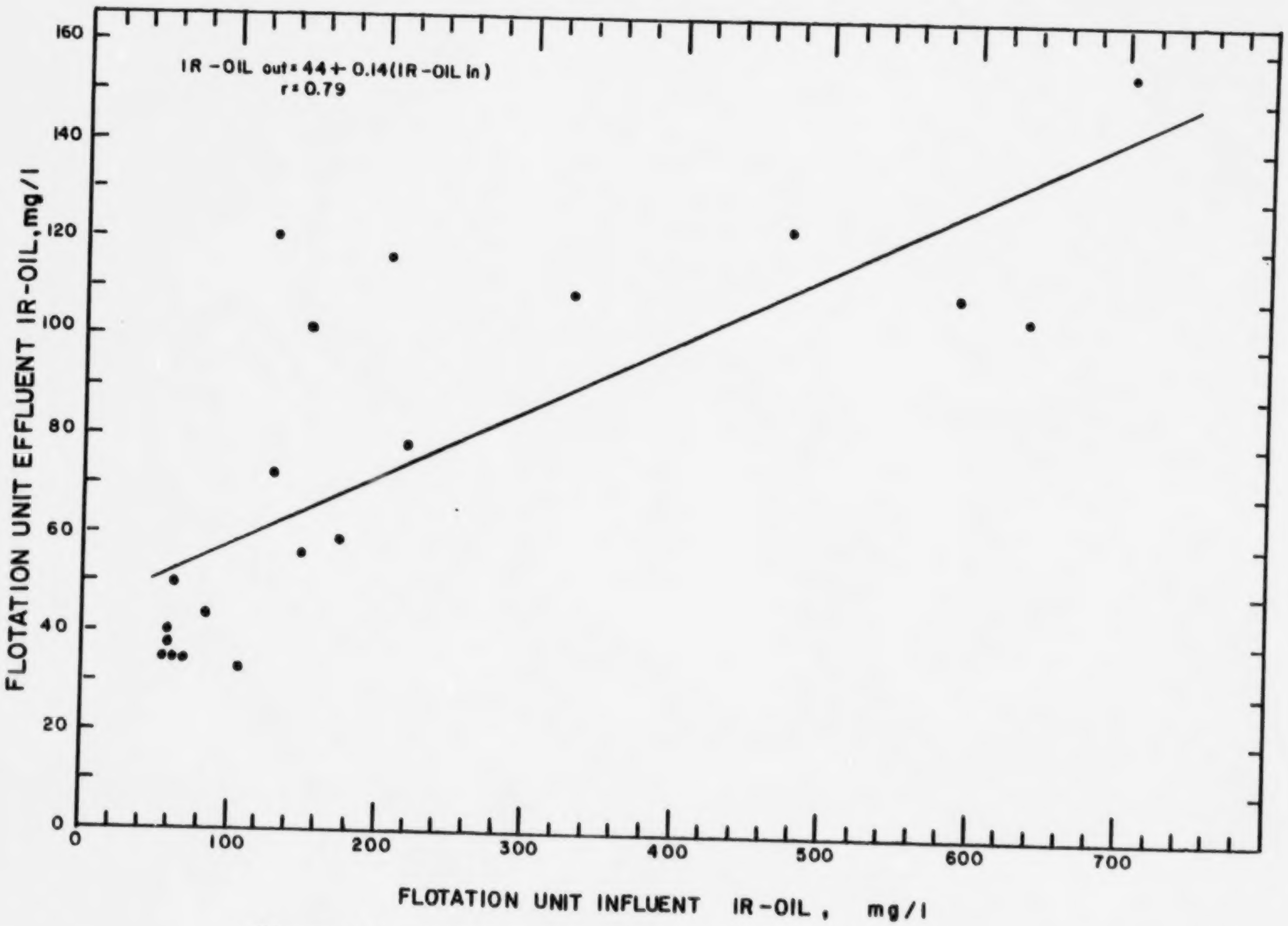


Figure 106. EI18CF flotation unit in-out IR-oil regression.

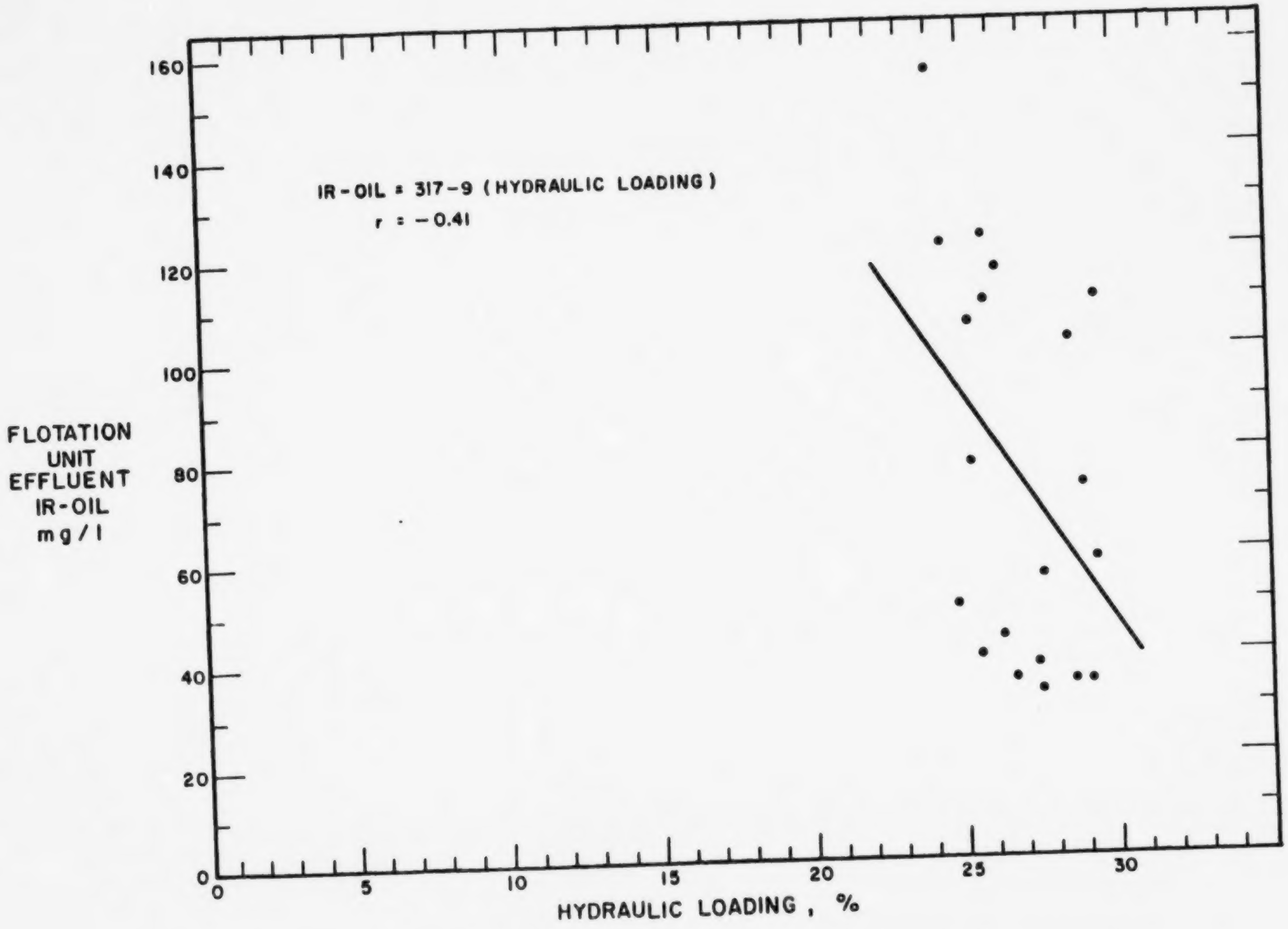


Figure 107. EI18CF flotation unit hydraulic loading - infrared oil regression.

TABLE 170. EI18CF FLOTATION UNIT SLUDGE DRAIN

Sample time		IR-Oil, mg/l	
Day	Hour	Final effluent	Sludge drain
01	1300	56	60
02	1300	78	88
04	1300	116	114
08	1300	33	29
09	1300	35	36
Mean		64	65
Minimum		33	29
Maximum		116	114

TABLE 171. EI18CF GRAVITY SEPARATOR OIL CONTENT

		IR-Oil, mg/l		
Sample time		Influent	Effluent (9--i)	
Day	Hour	8--i	Upstream of pump	Downstream of pump
01	0800	245	172	-
01	1300	298	147	-
02	0800	339	127	-
02	1300	441	217	-
03	0800	323	151	-
03	1300	253	327	-
04	0800	268	137	-
04	1300	222	204	-
05	0800	229	703	-
05	1300	262	474	-
06	0800	245	589	511
06	1300	270	638	351
07	0800	208	196	61
07	1300	286	82	82
08	0800	257	-	59
08	1300	813	360	106
09	0800	221	172	61
09	1300	294	131	64
10	0800	241	-	58
10	1300	188	-	54
Mean(1)		334	310	177
Minimum(1)		208	82	61
Maximum(1)		813	638	511

(1) Includes only tests when an IR-Oil was run upstream and downstream of pump.

TABLE 172. EI18CF SUSCEPTIBILITY TO SEPARATION TESTS ON GRAVITY SEPARATOR INFLUENT

	Settling times, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 3, 1000								
IR-Oil, mg/l	311	196	163	102	65	56	40	315
IR-Oil W/Silica Gel, mg/l	253	-	114	-	-	-	33	-
Test Number 2 Day 5, 1000								
IR-Oil, mg/l	163	155	143	98	69	47	38	180
IR-Oil W/Silica Gel, mg/l	135	-	98	-	-	-	31	-
Test Number 3 Day 7, 1000								
IR-Oil, mg/l	229	168	147	98	69	45	38	270
IR-Oil W/Silica Gel, mg/l	163	-	110	-	-	-	29	-
Average								
IR-Oil, mg/l	234	173	151	99	68	49	39	255
IR-Oil W/Silica Gel, mg/l	184	-	107	-	-	-	31	-

TABLE 173. EI18CF SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °C			pH	Specific gravity[(1)]
Day	Hour	8--i	9--i	9--0	9--0	9--0
01	08	39.5	40.0	40.0	6.5	1.137
02	08	40.0	38.0	38.0	6.2	1.137
03	08	41.5	39.5	38.5	6.3	1.135
04	08	39.5	38.5	38.5	6.3	1.145
05	08	38.5	38.5	37.5	6.1	1.140
06	08	40.5	37.5	37.5	6.2	1.144
07	08	39.5	39.5	37.5	6.2	1.137
08	08	39.5	39.5	38.0	6.1	1.145
09	08	40.5	39.5	38.0	6.4	1.136
10	08	40.0	40.5	38.0	6.3	1.145
Mean		39.9	38.1	38.2	6.3	1.140
Minimum		38.5	37.5	37.5	6.1	1.135
Maximum		41.5	40.5	40.0	6.5	1.145

Note: Sample point identification numbers (8--i, 9--i, 9--0) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 174. EI18CF BRINE TESTS AT MINOR SAMPLING POINTS

Sample time		IR-Oil, mg/l		Temperature, °C	
Day	Hour	5A20	6--0	5A20	6--0
04	08	249	192	40.5	57.0
06	08	222	392	39.0	53.0

Note: 5A20 is the low pressure separator effluent.
6--0 is the oil treater effluent.

TABLE 175. EI18CF SULFATE REDUCING BACTERIA

Sample point	Bacteria per milliliter
Sump - Bottom (14--B)	1,000,000
Low Pressure Separator - Out (5A20)	0
Oil Treater - Bottom (6--B)	0
Gravity Separator - Bottom (8--B)	10-100
Flotation Unit - Bottom (9--B) (1)	0
Sample Day and Hour: 04 at 16	

(1) Special Bottom Dump Line.

TABLE 176. EI18CF IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	56,625
Potassium (K)	400
Calcium (Ca)	4,030
Magnesium (Mg)	997
Barium (Ba)	323
Chloride (Cl)	102,000
Sulfate (SO_4)	5
Alkalinity (as HCO_3)	146
Iron (Total)	18
Sulfide (as H_2S)	0.15
Total Dissolved Solids	
Summation	164,000
Gravimetric	162,000
Sample Day and Hour: 10 at 14	

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on EI18CF. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil test results are listed in Table 177 and Table 178. The crude oil specific gravity, and surface tension test results fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one and are of primary significance for comparisons between platforms. Two equilibration tests were run, each at a different oil/water ratio.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil. Between-platform comparisons will be presented in a later section.

TABLE 177. EI18CF CRUDE OIL MISCELLANEOUS TESTS

Sample time		Temperature	Specific(2)	Surface tension(3)
Day	Hour	°C	gravity	dynes/cm
01	08	36.5	0.810	26
02	08	33.5	0.812	26
03	08	33.3	0.813	27
04	08	33.5	0.811	27
05	08	25.5	0.816	27
06	08	27.0	0.816	26
07	08	42.0	0.806	27
08	08	37.5	0.806	26
09	08	40.5	0.809	26
10	08	41.5	0.804	26
Mean		35.1	0.810	26
Minimum		25.5	0.804	26
Maximum		41.5	0.816	27

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
10	14	2.95	2.44

	Equilibration at 82°C Brine TDS = 164,000 mg/l	
Oil/Water Ratio	4/1	0.11/1
IR-Oil, mg/l	10	9
IR-Oil W/Silica Gel, mg/l	10	7
IR-Oil Filtered Brine, mg/l	16	12

---

(1) Samples taken from oil treater.
(2) Specific gravity reported for temperature in table.
(3) Surface tension measured and reported at ambient temperatures from 20.5°C to 33.2°C.

TABLE 178. EI18CF CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	480

Boiling range, °C	Percent recovered
Below - 200	37.1
20 - 250	23.4
250 - 300	27.3
300 - 350	7.5
350 - 400	2.1
400 - 450	0.3
450 - 500	0.0
Total	97.7

SECTION 15

PLATFORM SM130B

GENERAL

The ten-day testing survey was conducted on Platform SM130B from April 16 through April 25, 1980.

A description of the production facilities, the test program, and data presentation and evaluation are presented in this section.

Three survey team members arrived at the platform on April 13. The equipment was not unloaded until the evening of April 15 because of undulating seas. The equipment was set up that evening and the testing began the next morning. Oil company personnel unloaded the equipment and provided living quarters, work space, sample taps, and the utilities needed to conduct the Program.

A platform shut in on Day 6 caused the sampling schedule to be altered on that day. The sampling periods on Day 6 were 1600, 1800, 2000 and 2200.

FACILITIES AND OPERATIONS

Production From Wells

Twenty-one wells were producing. Five wells were shut in for a day or less. All wells flowed or were gas lifted to the low-pressure three-phase separator.

Eighteen wells were flowing and the other three wells were gas lifted. The average daily production calculated from well test data was 2,730 m^3/d (17,170 bpd) of oil, 631 m^3/d (3,966 bpd) of water, and 237,200 std m^3/d (8,377 Mcfd) of gas. The calculated water cut was 19 percent.

The measured oil production for the ten-day period averaged 2,554 m^3/d (16,067 bpd) or 6 percent less than the well test data. The measured water production averaged 690 m^3/d (4,340 bpd) or 9 percent more than the well test data.

Four percent of the oil was gas lifted and fifty-nine percent of the water was gas lifted.

Production Process System

TYPING GUIDE SHEET

SM130B is the newest platform in the survey with initial processing beginning in August, 1979. The flow of oil and water through the system is shown in Figure 108. Design and operating data on major vessels are presented in Table 179. The oil/water/gas flow is from the wells to the low-pressure gas-liquid separator.

A foam inhibitor, Dow Corning 200, is added to the produced fluids at the well manifold ahead of the low-pressure separator. No other oil treating or water treating chemicals are used on SM130B.

The oil flows from the low-pressure separator to Platform A for further treatment. The water flows through the desander to the corrugated plate interceptors (CPI).

Figure 109 is a flow schematic for the water treating system. The primary flow is the produced water from the low-pressure separator through the desander to the CPIs. This flow averaged 971 m^3/d. Water from the CPIs flows through the flotation unit and is discharged.

The skimmings from the CPIs and the flotation unit flow to the wet-oil tank. Miscellaneous drains discharge to the skim sump, and any oil recovered is pumped to the wet-oil tank. The water from the skim sump is discharged to the skim pile. Oil and water that accumulates in the wet-oil tank are pumped to the low-pressure separator. The wet-oil-tank pump substantially increased the flow through the water treating system when operating.

The test treater discharged into the water line from the low-pressure separator to the desander.

The final effluent flow was monitored continuously as described in the subsection on Flow Monitoring. The flows in Figure 109 were developed using this flow meter and the estimating procedures also described in the flow monitoring subsection.

SM130B is the only platform in the survey with a desander in operation. The desander consists of twelve hydrocyclones, six of which were in service. The hydrocyclones are used in parallel. In a hydrocyclone, pressure energy is converted into centrifugal force by tangentially feeding the produced water into the conical vessels. The centrifugal forces developed multiply the settling velocity of the suspended solids, driving them outward toward the conical wall and downward into a centrifugally accelerating spiral along the wall to the solids discharge point of the cone. The solids are discarged to a chamber beneath the cones. The chamber is isolated from the cones and flushed with utility water once every two hours.

The liquid phase being lighter, moves inwardly, and upwardly as a spiraling vortex to the liquid discharge. The desander inlet pressure averaged 97 kPag with the wet-oil-tank pump on and 57 kPag with the pump off.

The CPI units are gravity separators of proprietary design supplied by Monarch Separators, Inc. Oil separates as the water flows between parallel plates spaced approximately 2 cm (0.75 in.) apart. Figure 44 is an

EPA-287 (Cin.)
(4-76)

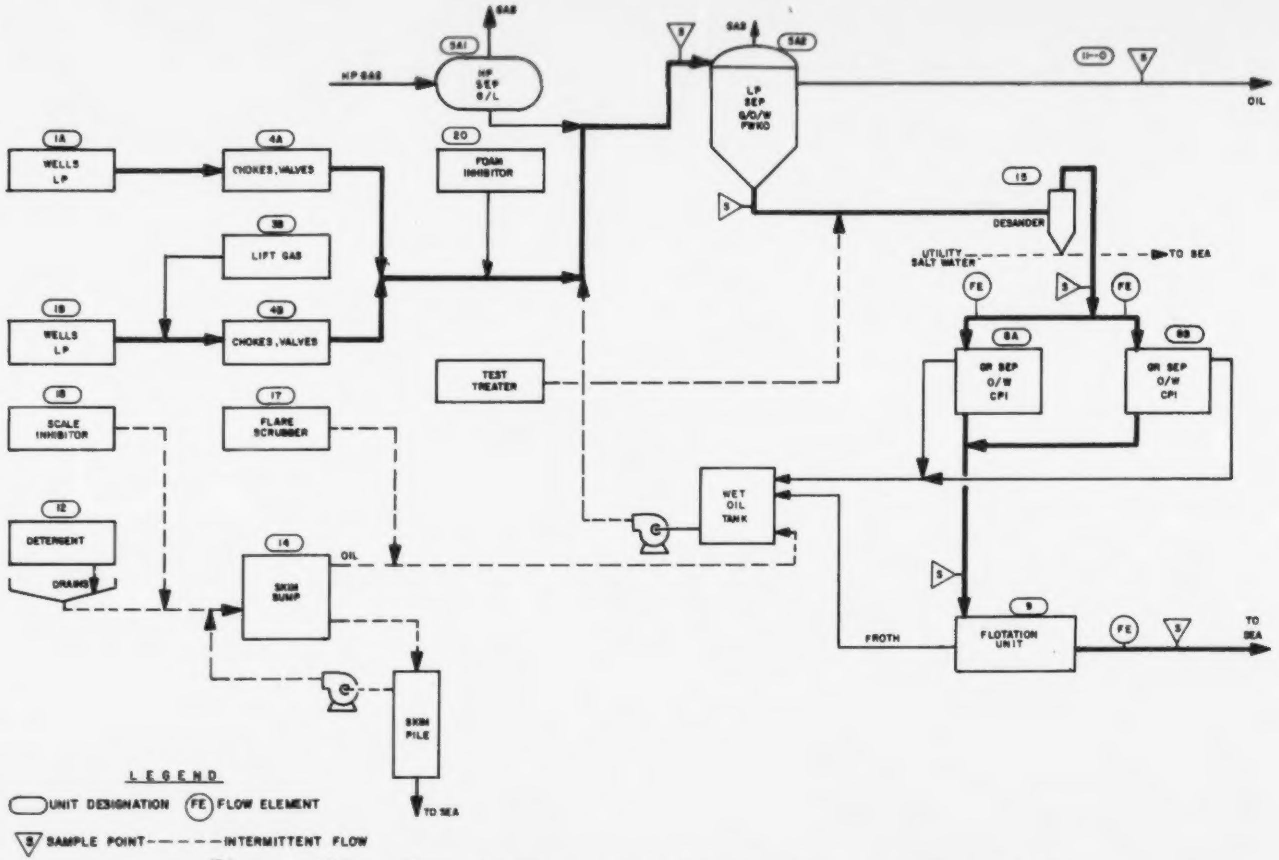
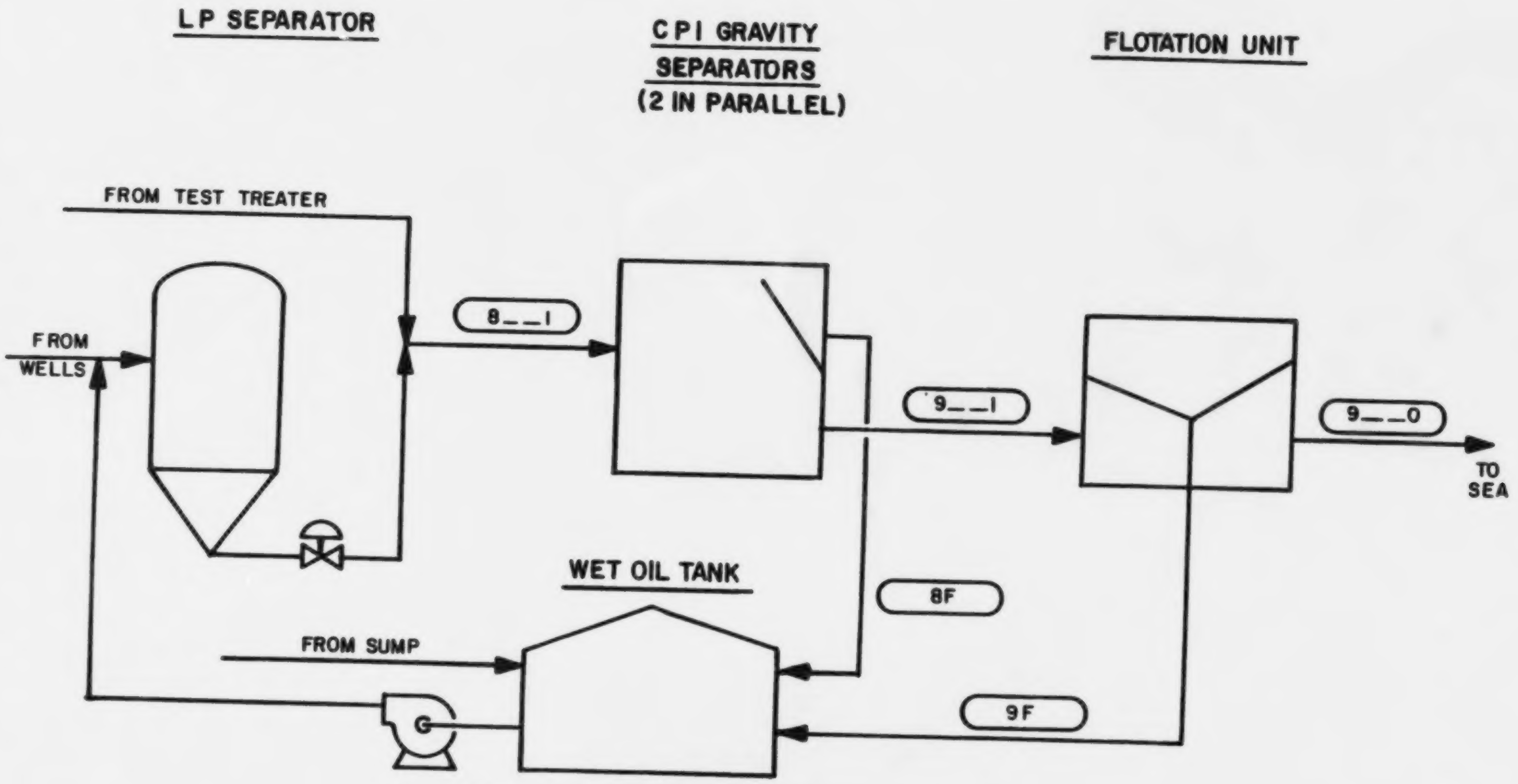

GAS
5A1
HP GAS
HP SEP G/L
1A
WELLS LP
4A
CHOKES, VALVES
20
FOAM INHIBITOR
3B
LIFT GAS
1B
WELLS LP
4B
CHOKES, VALVES
TEST TREATER
16
SCALE INHIBITOR
17
FLARE SCRUBBER
12
DETERGENT
DRAINS
14
SKIM SUMP
OIL
SKIM PILE
TO SEA
S
GAS
5A2
LP SEP G/O/W FWKO
11-0
S
OIL
S
15
DESANDER
UTILITY SALT WATER
TO SEA
FE
S
FE
8A
GR SEP O/W CPI
8B
GR SEP O/W CPI
WET OIL TANK
S
9
FLOTATION UNIT
FROTH
FE
S
TO SEA
LEGEND
UNIT DESIGNATION
FE FLOW ELEMENT
S SAMPLE POINT
INTERMITTENT FLOW

Figure 108. Flow diagram, production process system, SM130B.

TABLE 179. SM130B VESSEL DATA SHEET

Vessel description	VESSEL DESIGNATION ON FLOW DIAGRAM - FIGURE 15-1		
	5A2 Low pressure 3-phase separator	8A & 8B Gravity separator, CPI	9 Flotation unit, mechanical, dispersed gas
Trade Name or Vessel Type	Vertical Cylinder Cone-Bottom	Monarch(1)	Wemco Model 84
Design Parameters			
Dimensions, m, (ft)			
Diameter, O.D.	4.88(16)	-	-
Length, S.S.	3.66(12)	-	-
Length	-	-	6.91(22.7)(3)
Width	-	-	1.93(6.3)(3)
Separation Surface Area, m^2, (ft^2)			
Total	-	-	13.3(143)
Per Cell	-	-	3.33(35.8)
Separation Volume, m^3, (bbl)			
Total	-	-	17(110)
Oil Phase	-	-	-
Water Phase	-	-	-
Number of Cells	-	-	4
Flow Rate, m^3/day, (bpd)	-	3,820(24,000)(2)	6,135(38,585)
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)(5)	-	-	1,840(1,080)
Recycle Rate, Percent of Flow	-	-	-
Retention Time, min.	-	-	4
Average Operating Parameters			
Temperature, $^oC(^oF)$	40.9(106)	40.2(104)	40.1(104)
Pressure, kPag (psig)	630(91)	0(0)	0(0)
Flow Rate, m^3/d(bpd)(4)	971(6,107)	970(6,101)	690(4,340)
Flow Rate, Percent of Design	-	25	11
Overflow Rate Per Cell, $(m^3/d)/m^2$, (bpd/ft^2)	-	-	207(121)
Recycle Rate, Percent of Flow	-	-	-
Froth Flow, Percent of Flow	-	-	41

(1) Proprietary unit with two plate packs.
(2) Based on removing 40 μm oil drops.
(3) Separation area.
(4) Effluent flow.
(5) Overflow rate is surface area divided by flow rate.


LP SEPARATOR
C P I GRAVITY
SEPARATORS
(2 IN PARALLEL)
FLOTATION UNIT
FROM TEST TREATER
FROM
WELLS
8__I
9__I
9__0
TO
SEA
WET OIL TANK
8F
FROM SUMP
9F

WATER FLOW		8F	8__I	9F	9__I	9__0
	m^3/d	1	971	280	970	690
	bpd	6	6107	1761	6101	4340

Figure 109. SM130B water handling system flow schematic.

undimensioned representational sketch of a CPI unit.

The CPI units on SM130B each have two packs. There are three units but only two units were in operation. The approximate dimensions of each pack are 1 m high, 1 m wide, and 1.75 m long. Based on the manufacturer's recommended sizing procedure and the conditions prevailing on SM130B during the survey, the two CPI units in operation should accomplish the separation of 40-micron oil drops at flow rates up to 3,820 m^3/d (24,000 bpd). Average hydraulic loading was estimated to be 970 m^3/d (6,101 bpd), or 25 percent of design.

The flotation unit (Wemco 1 + 1, Model 84) is a proprietary four-cell unit with mechanical gas eduction. This type of unit was described in Section 6 and is depicted in Figure 6. The design flow for the unit is 6,135 m^3/d (38,585 bpd). The average operating flow based on effluent flow was 690 m^3/d (4,340 bpd) or 11 percent of design flow. The average froth flow was 280 m^3/d or 41 percent of the forward flow.

SITE SPECIFIC TEST PROGRAM

The planned test program for brine samples was accomplished as presented in Table 180. The number of samples to be taken in ten days and the time the samples were to be taken each day are listed.

In addition to the brine tests, the following tests were run on crude oil samples: temperature, specific gravity, viscosity, boiling range distribution, equilibration, and surface tension.

Particle size distribution tests were run and are reported in Section 16.

OPERATIONAL DATA AND OBSERVATIONS

Measurements, observations, and records of operations are reported in this subsection.

Flow Monitoring

The water flow patterns are shown in Figure 108 and Figure 109. The flotation unit effluent was monitored continuously after Day 2 at 0800. The flow was monitored with a turbine type flow meter. These flow rates are reported in Table 181. The flotation unit and CPI skimmings rates were calculated four times daily. The estimates were based on the rate of rise in the wet-oil tank. The average flow rates are shown in Figure 109.

Practically all the skimmings flow was from the flotation unit. The CPI skimmings were minimal. The CPI's oil skimming weirs were set high enough to build up an oil layer and skim more oil than water.

The wet-oil-tank pump is turned on and off automatically, controlled by a level control. The wet-oil tank is a large vessel and the on and off periods of the pump can be quite long in duration. The on periods averaged 5 hours with a maximum of 21 hours and the off periods averaged 6.5 hours with a maximum of 41 hours. The length of the on and off periods is

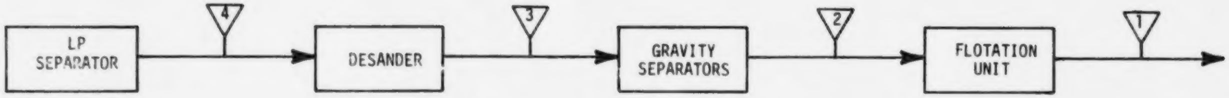


TABLE 180. SM130B TEST SCHEDULE FOR THE MAJOR BRINE TESTS

	SAMPLE POINTS							
	1		2		3		4	
	9--0		9--i		8K-i		5--0	
	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests	No. of tests	Time of tests
Field Tests								
Infrared Oil	20	8,13	20	8,13	20	8,13	10	8
Temperature	10	8	10	8	10	8	10	8
pH	10	8	-	-	-	-	-	-
Water Specific Gravity	10	8	-	-	-	-	-	-
Water Surface Tension(2)	10	8	-	-	10	3	-	-
IR-Oil W/Silica Gel	20	8,13	-	-	10	8	-	-
IR-Oil Filtered Brine	20	8,13	-	-	10	8	-	-
Susceptibility to Separation(3)	-	-	-	-	3	13	-	-
Laboratory Tests								
Gravimetric Oil	40	8,10,13,15	10	8	-	-	-	-
Suspended Solids	10	8	10	8	10	8	10	8
Ionic Analysis	1	(1)	-	-	-	-	-	-
Bacterial Culture	A maximum of five tests at sample points selected in the field.							
Particle Size Distribution (4)	3	13	3	13	3	13	-	-

(1) Sampling times not shown will be field scheduled.
(2) Extra samples when IR-Oil is high.
(3) IR-Oil w/Silica Gel at 0, 5, and 120 minutes.
(4) IR-Oil, IR-Oil w/Silica Gel, and filtered brine tests at same time.

NOTE: Time of tests listed is by military hour.

TABLE 181. SM130B MAJOR BRINE TESTS

		Gravity separator influent (8K-i)					Flotation unit influent (9--i)		Flotation unit effluent (9--0)							
			IR-Oil w/silica gel								IR-Oil w/silica gel				Flow rate	
Sample time		IR-Oil	Dispersed	Soluble	Filtered brine IR-Oil	Surface tension	GR-Oil	IR-Oil	GR-Oil	IR-Oil	Dispersed	Soluble	Filtered brine IR-Oil	Surface tension	Out	Skimmings
Day	Hour	mg/l	mg/l	mg/l	mg/l	dynes/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	dynes/cm	m^3/d	m^3/d
01	08	261	209	52	39	62	87	96	55	66	41	25	28	70	-	361
01	10	-	-	-	-	-	-	-	70	-	-	-	-	-	-	361
01	13	436	-	-	-	-	-	131	63	64	35	29	31	-	-	433
01	15	-	-	-	-	-	-	-	50	-	-	-	-	-	-	433
02	08	322	248	74	39	58	81	109	47	54	26	28	26	69	-	192
02	10	-	-	-	-	-	-	-	67	-	-	-	-	-	508	192
02	13	261	-	-	-	64	-	100	57	62	38	24	27	-	518	180
02	15	-	-	-	-	-	-	-	98	-	-	-	-	-	1,207	122
03	08	266	209	57	43	58	83	100	73	86	52	34	31	66	655	11
03	10	-	-	-	-	-	-	-	72	-	-	-	-	-	693	11
03	13	261	-	-	-	-	-	113	77	74	42	32	35	-	676	8
03	15	-	-	-	-	-	-	-	64	-	-	-	-	-	680	8
04	08	619	540	79	41	65	106	126	40	52	27	25	27	69	121	580
04	10	-	-	-	-	-	-	-	49	-	-	-	-	-	577	667
04	13	379	-	-	-	63	-	100	42	39	14	25	27	-	819	587
04	15	-	-	-	-	-	-	-	75	-	-	-	-	-	742	508
05	08	314	266	48	43	59	124	153	30	40	16	24	29	68	324	352
05	10	-	-	-	-	-	-	-	44	-	-	-	-	-	940	476
05	13	11,549	-	-	-	51	-	580	53	54	35	19	30	-	442	715
05	15	-	-	-	-	-	-	-	46	-	-	-	-	-	478	700
06	16	218	105	113	41	57	179	196	25	33	12	21	28	72	90	95
06	18	-	-	-	-	-	-	-	35	-	-	-	-	-	454	162
06	20	610	-	-	-	64	-	187	49	44	20	24	35	-	1,240	253
06	22	-	-	-	-	-	-	-	42	-	-	-	-	-	1,068	253
07	08	501	436	65	39	60	116	144	34	40	17	23	30	67	1,049	253
07	10	-	-	-	-	-	-	-	40	-	-	-	-	-	565	224
07	13	401	-	-	-	62	-	144	35	35	14	21	29	-	601	169
07	15	-	-	-	-	-	-	-	39	-	-	-	-	-	1,111	190
08	08	349	292	57	41	58	119	144	32	40	13	27	29	67	1,046	291
08	10	-	-	-	-	-	-	-	42	-	-	-	-	-	1,002	291
08	13	322	-	-	-	59	-	113	38	35	15	20	28	-	488	102
08	15	-	-	-	-	-	-	-	36	-	-	-	-	-	512	269
09	08	418	336	82	43	57	109	131	30	36	13	23	34	68	994	238
09	10	-	-	-	-	-	-	-	38	-	-	-	-	-	862	293
09	13	445	-	-	-	60	-	131	44	35	10	25	32	-	501	123
09	15	-	-	-	-	-	-	-	40	-	-	-	-	-	424	272
10	08	1,351	1,090	261	44	62	150	196	46	46	15	31	32	68	777	282
10	10	-	-	-	-	-	-	-	32	-	-	-	-	-	575	179
10	13	1,678	-	-	-	62	-	118	30	27	13	14	29	-	877	174
10	15	-	-	-	-	-	-	-	32	-	-	-	-	-	545	172
Minimum		218	105	52	39	51	81	96	25	27	10	14	26	66	90	8
Maximum		11,549	1,090	261	44	65	179	580	98	86	52	34	35	72	1,240	715

dependent on the rate of skimmings from the flotation unit. The wet-oil-tank pumping rate was 545 m^3/d, substantially increasing the flow through the water treating system when it was on.

Well Test Data

The well test data provided by the operator are listed in Table 182. The wells are grouped according to lift method. The table also shows whether a well produced all or only part of the ten-day survey period.

TABLE 182. SM130B WELL TEST DATA

Location	Pressure, kPag (psig)	Pressure drop, point or description	Pressure drop, kPag (psig)
Formation (SIBHP)	14,480-18,970 (2,100-2,750)	perforations, static head, pipes	8,620-17,870 (1,250-2,590)
Flowing Tubing Pressure	1,100-5,860 (160-850)	chokes, valves, pipes	470-5,230 (70-760)
Low Pressure Separator	600-680 (87-99)	control valve, pipes	520-600 (75-87)
Desander	40-120 (6-17)	hydrocyclone, pipes	40-120 (6-17)
CPI	0		

Pressure Drops Through System

The formation pressures and the flowing tubing pressures for each well were obtained from well test data. Table 183 presents the ranges and traces the pressure drops from the producing formation through the system. The table includes only the wells producing water.

Table 183 shows that the greatest pressure drops occur from the formation to the chokes, substantial drops occur at the chokes, and more minor drops from the chokes on.

Chemical Addition

No water treating chemicals were added on a regular basis on SM130B.

TABLE 183. SM130B PRESSURE DROPS THROUGH SYSTEM

Well	Formation	TVD ft	Gas Mcfd	Oil bpd	Water bpd	Lift gas Mcfd	Pressure, psig SIBHP	Pressure, psig FTP	Choke size 1/64 in.	API gravity	Days of production
Flowing to Low Pressure Separator											
1	"J" D	5,480	568	1,526	0	0	2,650	690	26	31.9	All
2	"I_2" D_1	6,140	94	215	721	0	2,270	180	32	27.1	All
3	"I_{10}" C_2	7,500	199	644	114	0	2,500	420	24	29.9	All
5	"J" C_2	5,110	423	1,245	0	0	2,420	560	26	33.0	All
7	"J" C_2	5,160	1,727	1,108	0	0	2,300	1,100	26	27.2	All
8	"J" E	6,430	435	303	209	0	2,100	850	18	18.6	1-8,10
10	"J" D_1	5,800	744	972	0	0	2,550	1,100	20	28.9	All
11	"H_2" D	5,100	370	1,534	0	0	2,030	520	28	26.0	All
14	"I_2" D	5,280	420	1,506	0	0	2,160	580	24	26.0	1,2,3(1500),4-10
16	"I_4" C_2	7,350	215	466	522	0	2,320	280	30	32.3	All
20	"I_2" C_2	6,930	384	1,200	0	0	2,300	630	24	32.5	All
21	"I_2" D_2	7,800	397	1,447	0	0	2,320	530	26	28.9	All
22	"H_2" C_2	6,330	151	675	0	0	-	350	21	26.9	All
25	"H_8" D_2	5,620	329	1,294	0	0	2,150	600	26	31.3	All
26	"I_2" D	6,620	374	1,311	0	0	2,150	660	24	27.1	All
27	"I_2" C_5	8,100	149	380	165	0	2,240	200	28	33.0	All
28	"I_{10}" C_5	7,360	287	768	0	0	2,310	520	21	39.4	All
29	"I_{10}" C_2	5,890	984	678	0	0	1,830	670	26	33.6	All
Total (Average)		-	8,250	17,272	1,731	-	-	-	-	(29.6)	
Gas Lift to Low Pressure Separator											
6	"I_{10}" C_2	8,880	188	176	594	186	2,690	200	34	32.0	1-5,6(PM),7-10
9	"J" C_4	5,800	170	321	1,708	540	2,550	210	open	23.0	1-5,6(PM),7-10
13	"I_{10}" D_1	5,970	116	249	188	449	2,750	160	open	23.7	1-5,6(PM),7-10
Total (Average)		-	474	746	2,490	1,175	-	-	-	(26.2)	
Combined Total (Average)		-	8,724	18,018	4,221	1,175	-	-	-	(29.2)	

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

A foam inhibitor, Dow Corning 200, was added to the produced fluids at the well manifold. The foam inhibitor was diluted with diesel to a concentration of 15 percent. The diluted mixture was fed at a concentration of 3.5 ppmv.

Methanol was added to the lift gas to prevent hydrate formation.

Observations and Operator Reports

An effort was made to record any event that could affect effluent oil content. The operators were requested to provide information on upsets and intermittent operational or maintenance procedures and the survey team made their own observations.

The flotation unit skimming rate varied widely the first five days, ranging from 8 to 715 m^3/d. The skimming rate was much more consistent during the last five days, ranging from 95 to 293 m^3/d. The skimming rate was the lowest on Day 3, ranging from 8 to 11 m^3/d. Only one of the flotation unit cells was skimming on Day 3. The skimming was substantially increased on Day 4 when it averaged 586 m^3/d and ranged from 508 to 667 m^3/d. This skimming rate was in excess of the wet-oil-tank pump capacity of 545 m^3/d. In order to maintain the wet-oil-tank level, it was necessary to drain liquid to the skim sump. The highest skimming rates occurred on the afternoon of Day 5.

Wells were tested in either a test separator or a test treater. The test separator separated the production into gas and liquid streams. The test treater separated the production into three streams; gas, oil and water, and metered the streams individually. The water stream is discharged to the produced water line from the low-pressure separator to the desander. Well 9 was tested in the test treater on Day 5 from just after the 1000 sample period until 1600. Well 9 produced water at a rate of 272 m^3/d (1,708 bpd) during the test. This is more than any other well and 40 percent of the total water production on SM130B. During the 1300 sample period on Day 5 it was visually observed that the flow from sample point 8K-i was highly variable in oil content and at times very high in oil content.

The platform was shut in on Day 6 at 0600 for pipeline work. Sampling was started about 1600, 1/2 hour after flow through the flotation unit started. The gas-lift wells, which produced about 59 percent of the water, began production about the time of the 1800 sample period. The other two sample periods on Day 6 were 2000 and 2200.

Another shut in occurred on Day 9 right after the 1000 sample period. The flowing wells were shut in for about 1 hour, and the gas-lift wells for about 2 hours.

The lift gas injection rate was increased by about 30 percent when production was resumed after the shut in on Day 6. This substantially increased the water production rate until the lift gas injection rate was decreased on Day 9 after the 1300 sample period.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

Well 8 was taken out of production on Day 9 and gas-lift valves installed in preparation for converting the well from flowing to gas lift. Some of the calcium chloride completion fluid entered the tubing while installing the gas lift valves. The well was opened up on Day 10 during the 0800 sample period, but no lift-gas piping had been hooked up. The well had "loaded up" while it was shut in, and showed a flowing tubing pressure of only 690 kPag with a correspondingly low flow rate.

Rains and deck washings result in flow to the skim sump and any oil recoved is pumped to the wet-oil tank. No rains occurred during the test period. Deck washings occurred on the afternoon of Day 1, after the 1500 sample period on Day 9, and just before the 1000 sample period on Day 10.

The skim sump was flushed on Day 5 after the 1500 sample period. The flushing included the addition of 19 dm^3 of a scale inhibitor, Tretolite SP36.

DATA PRESENTATION AND EVALUATION

Comprehensive data tables, summary tables and graphs for SM130B are interspersed in the text of this section.

Effluent Oil Content

Table 181 presents a listing of oil content test results for the major sampling points. Figure 110 presents a plot of GR-Oil in and out of the flotation unit versus time. Figure 111 presents the same plot for IR-Oil content. The IR-Oil time-indexed plot is based on two test results per day. The GR-Oil time-indexed plot is based on one influent and four effluent test results per day.

The tabulated data and time-indexed plots show that the flotation unit influent is relatively uniform with only one of the 20 IR-Oil contents over 200 mg/l. The one influent value over 200 mg/1 (580 mg/l) occurred on Day 5 at the same time as the highest CPI influent value. The high oil carried through the flotation unit as a higher than average value. Day 5 is the day that Well 9 was being tested in the test treater during the 1300 sample period. Well 9 produces 272 m^3/d of water and the water from the test treater is discharged to the line to the desander. High oil contents in the water from the test treater could have contributed to the high effluent value.

The highest flotation unit effluent IR-Oil was on Day 3. The flotation unit skimming rate ranged from 8 to 11 m^3/d, far below the average of 280 m^3/d. Only one of the flotation unit cells was skimming on Day 3. The unit was not skimming enough for effective oil removal with a dispersed gas flotation unit.

No reason is known for the high effluent values on Days 1 and 2.

The minor elevation in oil content on Day 10 at 0800 may have been caused by a flow of calcium chloride solution from Well 8.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA: OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

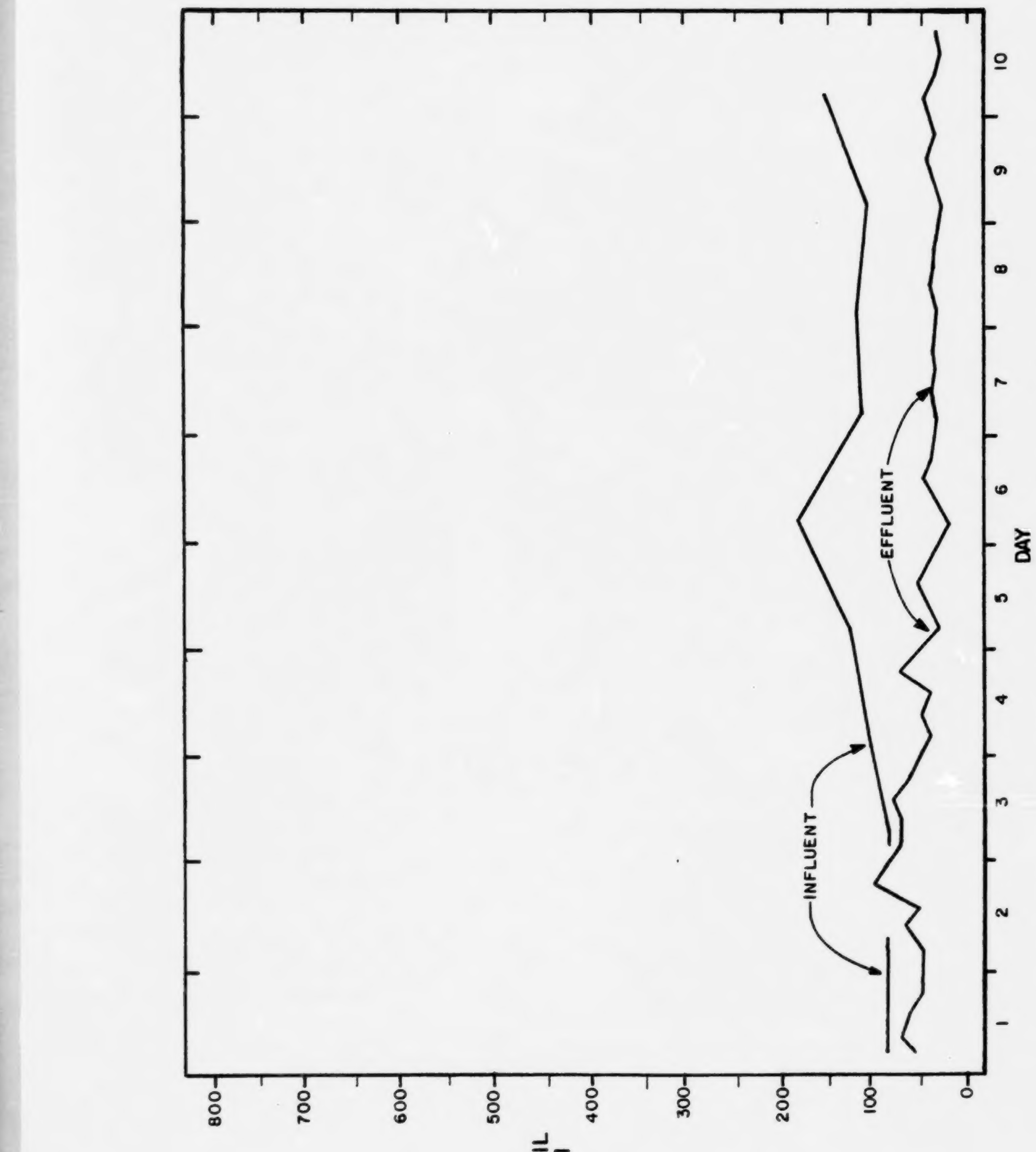


Figure 110. SM130B flotation unit performance, GR-oil vs time.

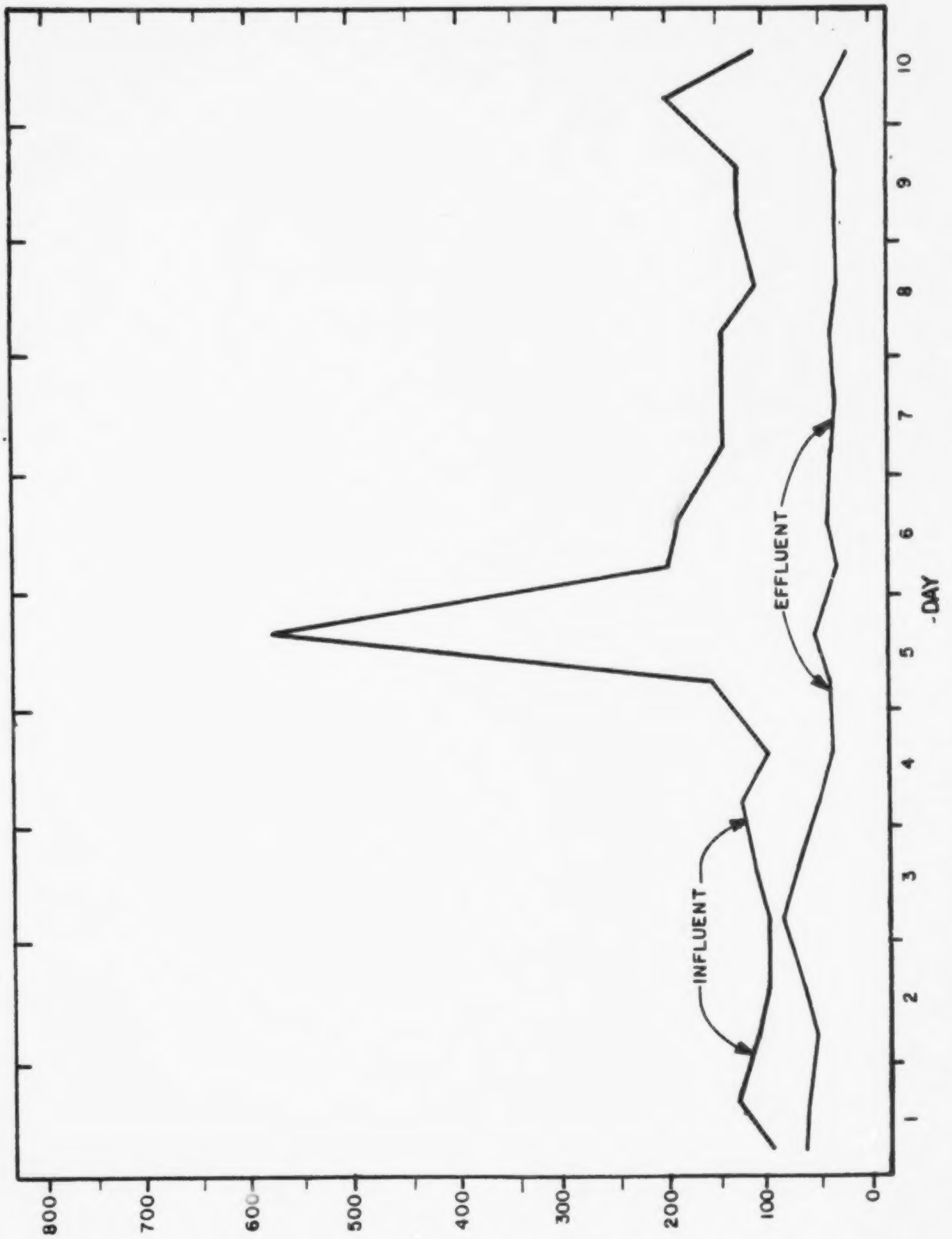


Figure 111. SM130B flotation unit performance, IR-oil vs time.

The ranges of test results are as follows:

Flotation Effluent GR-Oil - 25 to 98 mg/l,
Flotation Effluent IR-Oil - 27 to 86 mg/l,
Flotation Influent GR-Oil - 81 to 179 mg/l,
Flotation Influent IR-Oil - 96 to 580 mg/l.

Flotation unit effluent oil content histograms for the two test methods are presented in Figure 112 and Figure 113. Figure 114 is a regression plot of effluent GR-Oil versus IR-Oil. In comparing oil content test results by the two methods, it should be remembered that the samples were taken about one minute apart from a flowing stream. Therefore, the comparisons include time-dependent sample differences as well as normal sampling and testing variations.

Table 184 presents a summary comparison of test results by the two methods.

The data presented in Table 184 and the histograms indicate that the effluent mean oil content is the same by the IR-Oil test method as by the GR-Oil test method. The regression plot and the correlation coefficient of 0.91 shown in Figure 114 indicate a significant relationship between results by the two test methods.

All test results for dispersed oil and soluble oil as measured by the IR-Oil w/Silica Gel test are listed in Table 181. A summary of these test results on the flotation unit effluent is presented in Table 185.

An average of 52 percent of the oil in the effluent was soluble oil and 48 percent was dispersed oil.

Linear regression plots of dispersed oil versus IR-Oil and GR-Oil are presented in Figure 115. Extrapolations of the linear regression lines to zero dispersed oil indicate a residual IR-Oil of 20 mg/l and a residual GR-Oil of 21 mg/l after all dispersed oil is removed. The mean soluble oil content of the flotation unit effluent was 25 mg/l.

The mean soluble oil content of the gravity separator influent was 89 mg/l, significantly higher than the mean of 25 mg/l of the flotation unit effluent.

Surface Tension

All surface tension test results are listed in Table 181. The mean surface tension of the gravity separator influent is 60 dynes/cm and of the flotation effluent is 68 dynes/cm. The range for flotation effluent test results was from 66 to 72 dynes/cm. The linear regression equation for effluent IR-Oil and surface tension is:

$$\text{IR-Oil} = 254-3.0\ (\text{Surface Tension})$$
$$r = -0.32$$

A decrease in IR-Oil content of 3 mg/l is indicated for each 1 dyne/cm

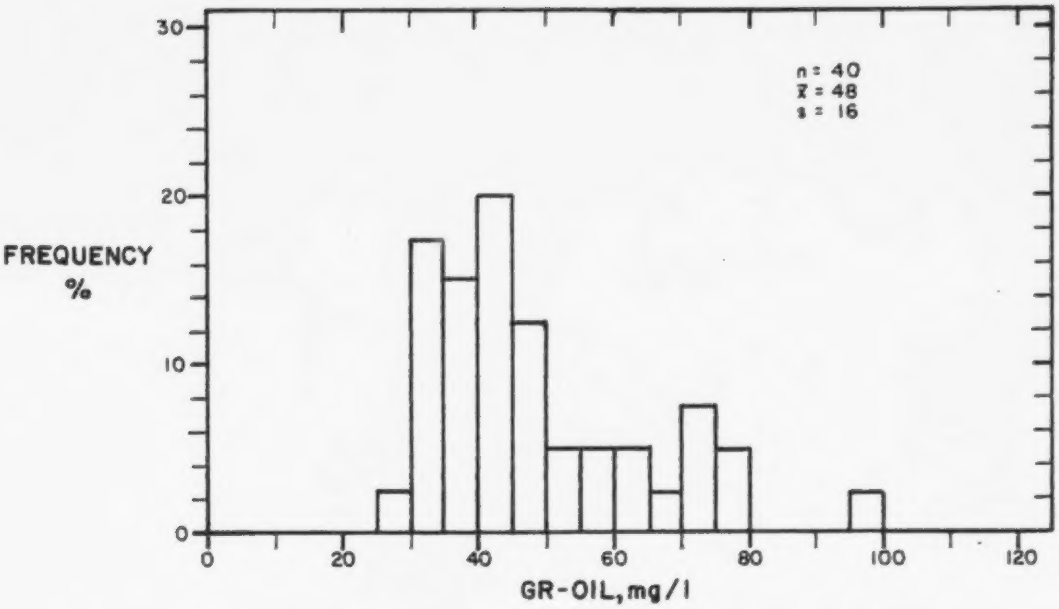


Figure 112. SM130B flotation unit effluent, GR-oil histogram.

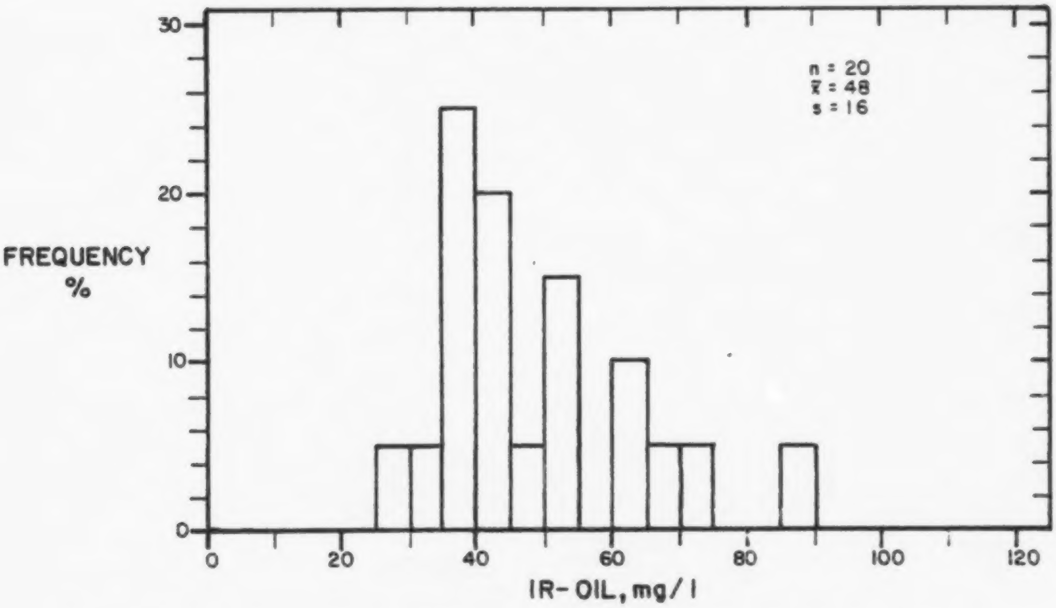


Figure 113. SM130B flotation unit effluent, IR-oil histogram.

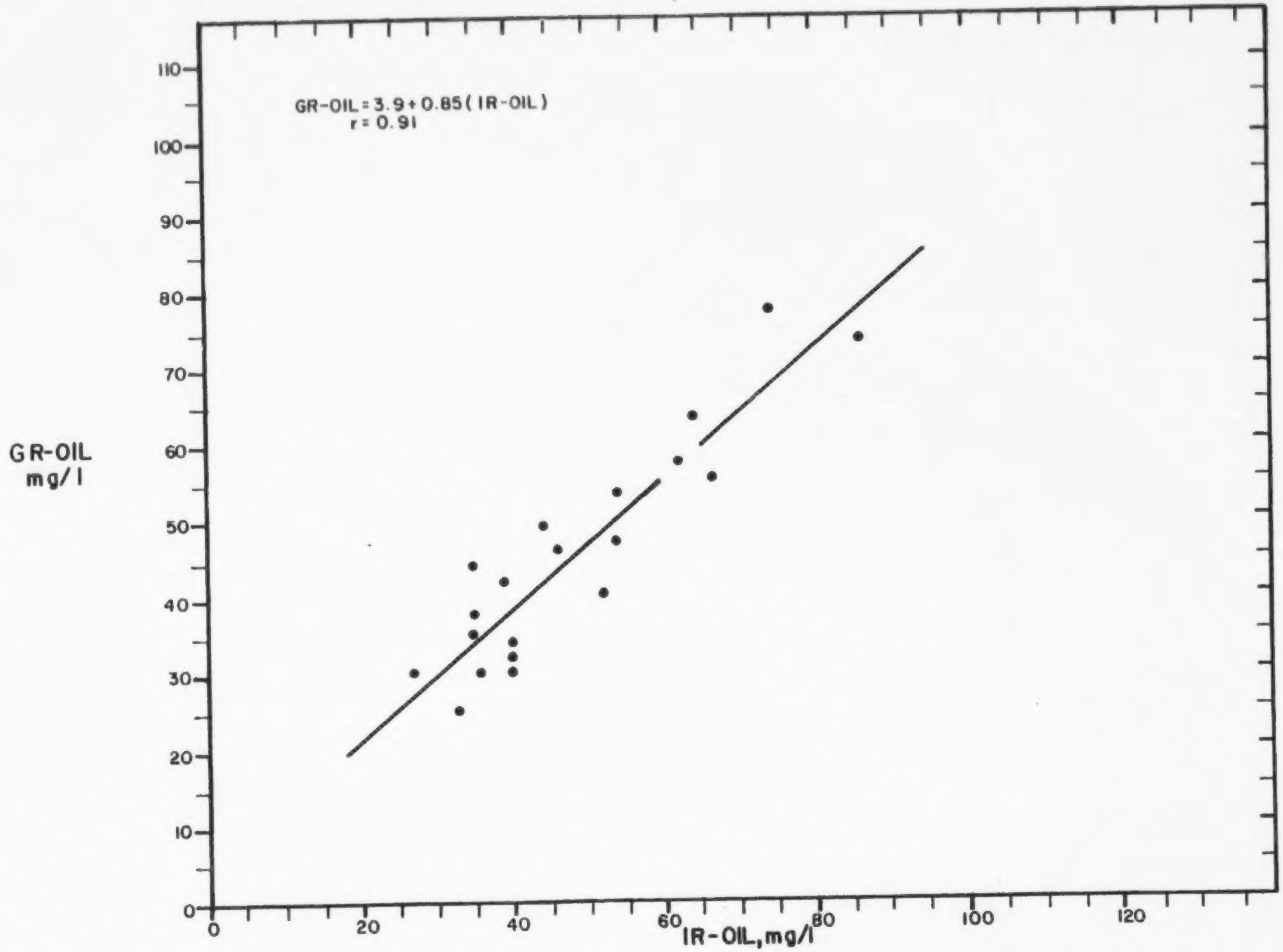


Figure 114. SM130B flotation unit effluent, infrared-gravimetric regression.

TABLE 184. SM130B FLOTATION UNIT EFFLUENT GR-OIL AND IR-OIL COMPARISON

	Oil content	
	GR-Oil	IR-Oil
Number of tests, (n)	40	20
Mean, ($\bar{x}$), mg/l	48	48
Minimum, mg/l	25	27
Maximum, mg/l	98	86
Standard Deviation,(s), mg/l	16	16
	Paired tests	
Number, (n)	20	
Mean of Differences, ($\bar{\Delta}$), mg/l	3.1	
Standard Deviations, (s_Δ), mg/l	6.3	

TABLE 185. SM130B SOLUBLE OIL SUMMARY

	Flotation effluent (9-10)		Proportion of total, percent
Analysis or test	Range mg/l	Mean mg/l	
IR-Oil	27-86	48	100
Dispersed Oil	10-52	23	48
Soluble Oil	14-34	25	52

increase in surface tension.

Suspended Solids

The suspended solids tests were run on the low-pressure separator effluent, the gravity separator influent, and the flotation unit influent and effluent. The data are recorded in Table 186 and Table 187 and a suspended solids summary for SM130B is presented in Table 188.

The data in Table 188 indicate that more than half of the solids were Freon soluble. The data also indicate an increase in Freon insoluble suspended solids across the flotation unit. The SM130B effluent iron content was 15 mg/l which is one of the higher iron concentrations for the produced brines in this survey. It is possible that some of the iron was oxidized in the flotation unit and that there actually was an increase in Freon insoluble suspended solids across the flotation unit but the precision of the test is not adequate for a positive answer.

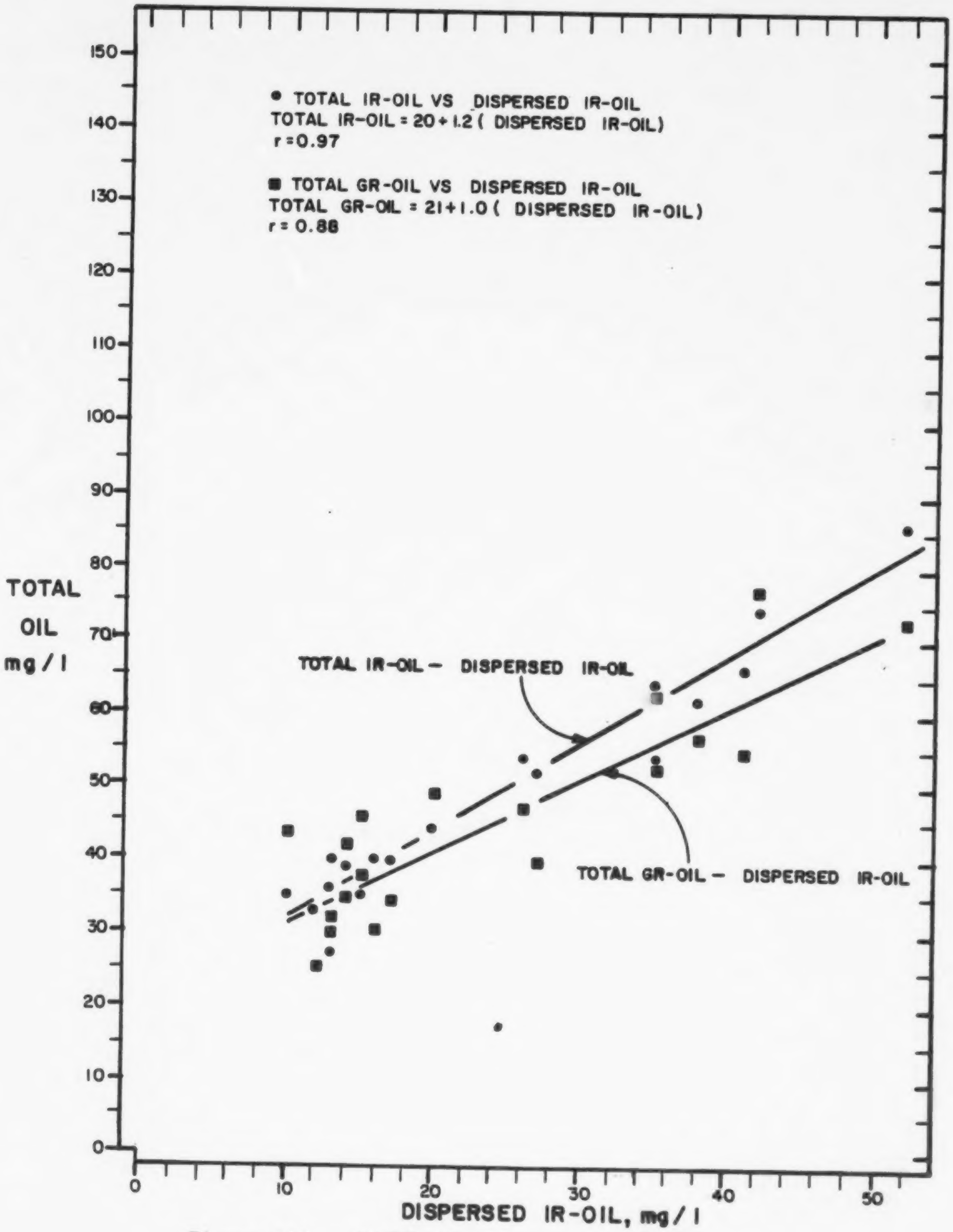


Figure 115. SM130B flotation unit effluent, total oil - dispersed oil regression.

TABLE 186. SM130B SUSPENDED SOLIDS TESTS

Sample time		Gravity separator, in (8K-i)					Flotation unit, in (9--i)					Flotation unit, out (9--0)				
Day	Hour	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l	Total mg/l	Freon soluble mg/l	Freon insoluble mg/l	Acid soluble mg/l	Fixed mg/l
01	08	45	45	2	2	0	48	48	3	3	0	49	31	19	19	0
02	08	52	52	1	1	0	52	49	3	3	0	41	21	20	20	0
03	08	49	45	4	4	0	42	42	0	0	0	51	37	13	13	0
04	08	44	43	1	1	0	44	44	0	0	0	13	9	4	4	0
05	08	58	57	0	0	0	56	55	1	1	0	32	18	14	14	0
06	16	63	56	7	1	6	40	37	3	3	0	21	21	0	0	0
07	08	68	62	6	5	1	50	46	4	4	0	19	16	3	3	0
08	08	56	53	3	3	0	42	39	3	3	0	25	14	11	11	0
09	08	56	56	0	0	0	44	44	0	0	0	27	26	1	1	0
10	08	54	54	0	0	0	55	55	0	0	0	28	11	17	17	0
Minimum		44	43	0	0	0	40	37	0	0	0	13	9	0	0	0
Maximum		68	62	7	5	6	56	55	4	4	0	51	37	20	20	0

TABLE 187. SM130B BRINE TESTS ON LOW PRESSURE SEPARATOR EFFLUENT (5--0)

Sample time Day	Sample time Hour	IR-Oil mg/l	Temperature °C	Suspended Solids Total mg/l	Suspended Solids Freon soluble mg/l	Suspended Solids Freon insoluble mg/l	Suspended Solids Acid soluble mg/l	Suspended Solids Fixed mg/l
01	08	279	42.0	56	58	1	1	0
02	08	305	41.5	66	55	11	10	1
03	08	253	41.0	55	45	10	10	0
04	08	418	41.0	49	49	0	0	0
05	08	253	42.0	53	45	7	7	0
06	16	59	40.5	56	50	6	6	1
07	08	458	41.5	62	48	13	13	0
08	08	379	42.5	44	44	0	0	0
09	08	340	42.0	52	52	0	0	0
10	08	981	41.5	56	51	4	4	0
Minimum		59	40.5	44	44	0	0	0
Maximum		981	42.5	66	58	13	13	1

TABLE 188. SM130B SUSPENDED SOLIDS SUMMARY

Suspended Solids	Average suspended solids, mg/l 5--0	8K-i	9--i	9--0
Total	55	55	47	31
Freon Soluble	50	52	46	20
Freon Insoluble	5	2	2	10
Acid Soluble	5	2	2	10
Fixed	0	1	0	0

The desander was between sample point 5--0 and sample point 8K-i. The mean Freon insoluble solids drop 3 mg/l between these points. This is a relatively insignificant change especially considering the poor precision of the test.

Figure 116 presents time-indexed plots of Freon insoluble suspended solids in the flotation unit influent and effluent, and of flotation effluent dispersed oil. All samples were taken at the same time, 0800 each day. The linear regression equation for effluent dispersed IR-Oil and effluent Freon insoluble suspended solids is:

$$\text{Effluent Dispersed Oil} = 15 + 0.77\ (\text{Freon Insoluble S.S.})$$
$$r = 0.43$$

Filtered Brine

The filtered brine IR-Oil content of the SM130B effluent was in the range of 26 to 35 mg/l with a mean of 30 mg/l. The filtered brine mean IR-Oil content of the gravity separator influent was 41 mg/l.

Flotation Unit Performance

Figure 117 is a regression plot of IR-Oil in and out of the flotation unit. The slope of the linear regression line is -0.0063 indicating little effect of influent oil on effluent oil.

Figure 118 is a regression plot of flotation unit effluent IR-Oil content and percent hydraulic loading. The slope of the linear regression line is -0.28, indicating a moderate inverse effect of hydraulic loading on effluent oil.

The lack of the expected relationships between effluent oil and influent oil or hydraulic loading may be because of the stable influent oil and the low hydraulic loading. All but one of the influent IR-Oil contents were less than 200 mg/l. The hydraulic loading was in the range of 1.5 to 20 percent of the design capacity of the flotation unit.

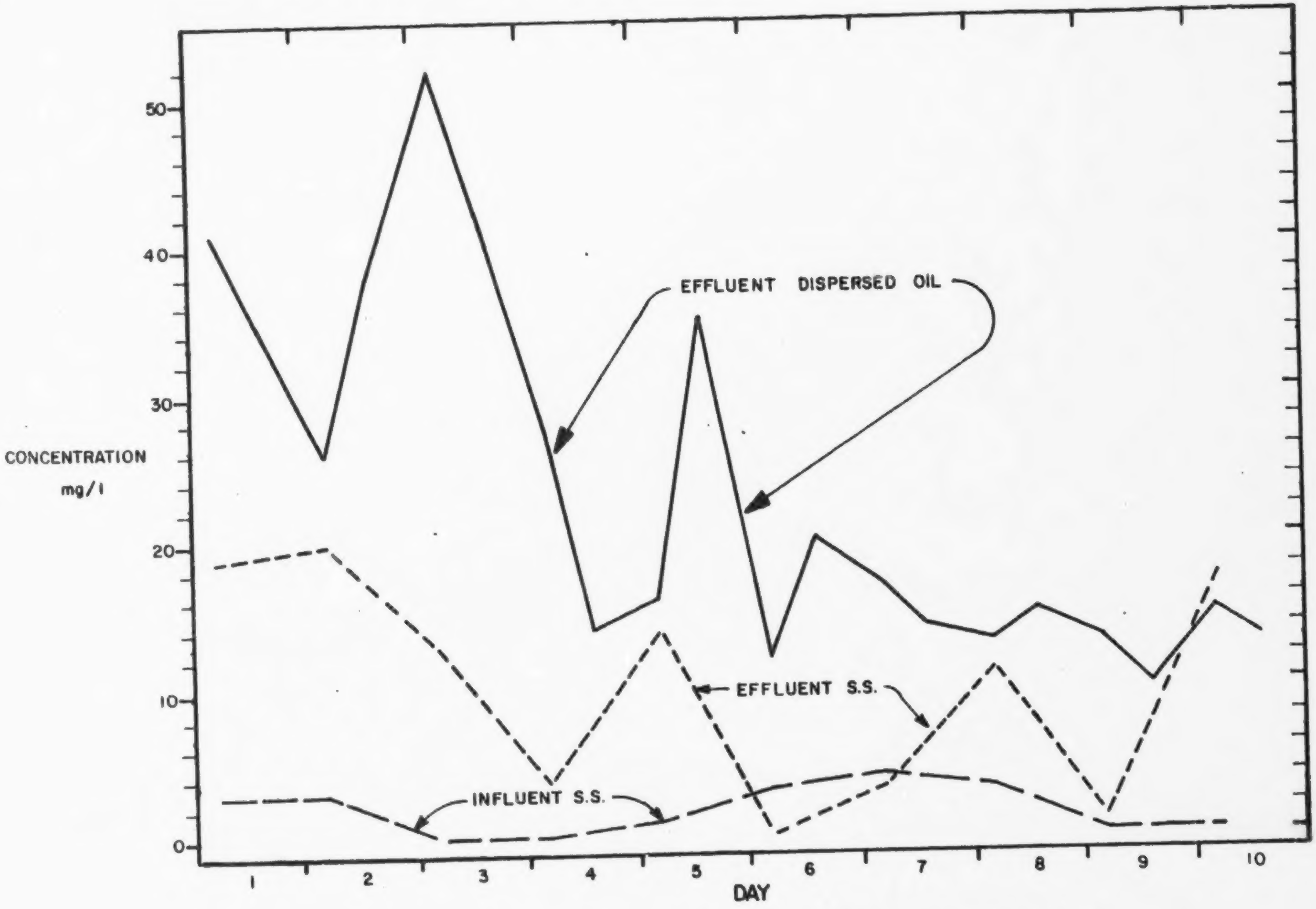


Figure 116. SM130B flotation unit Freon insoluble suspended solids.

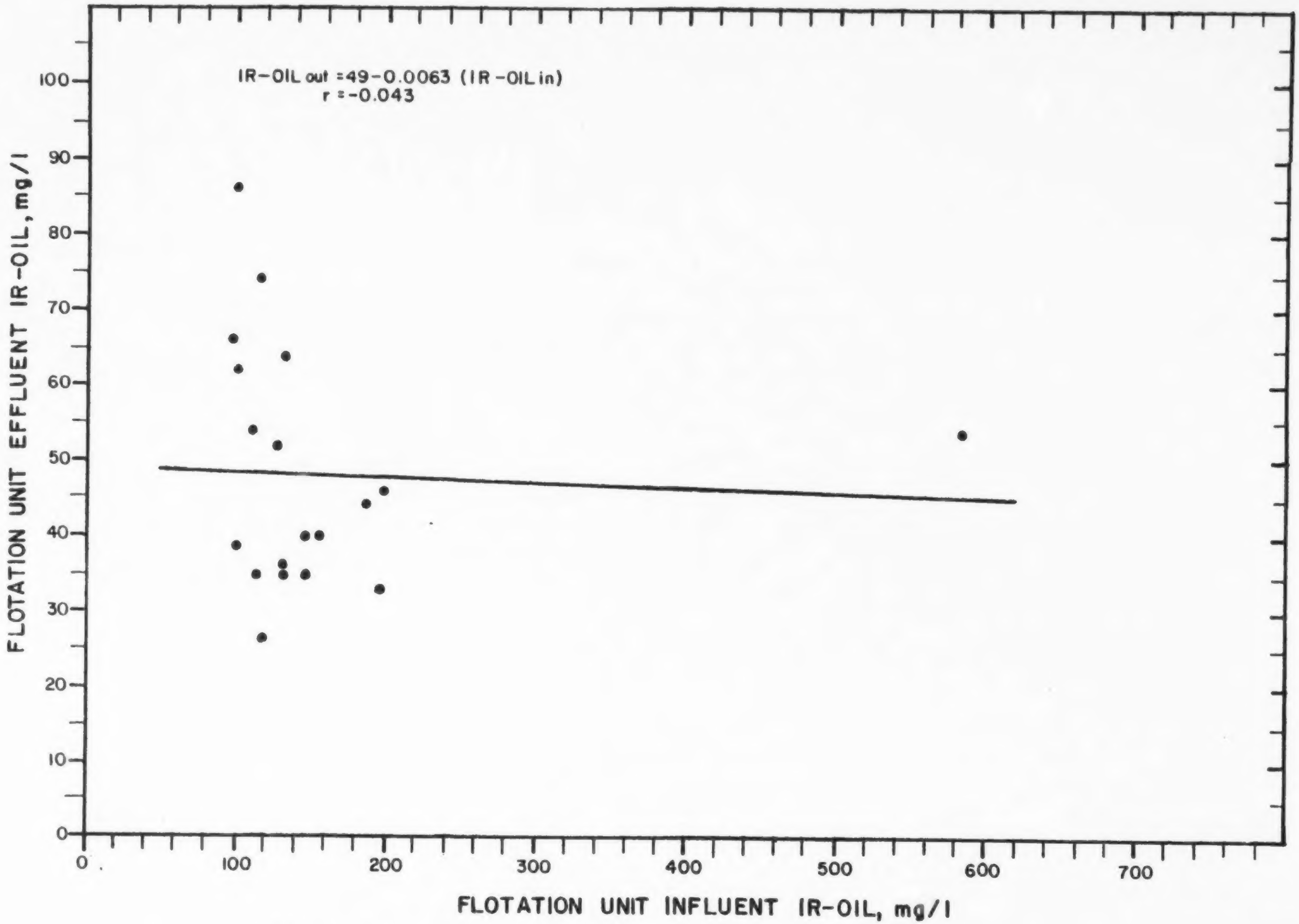


Figure 117. SM130B flotation unit in-out IR-oil regression.

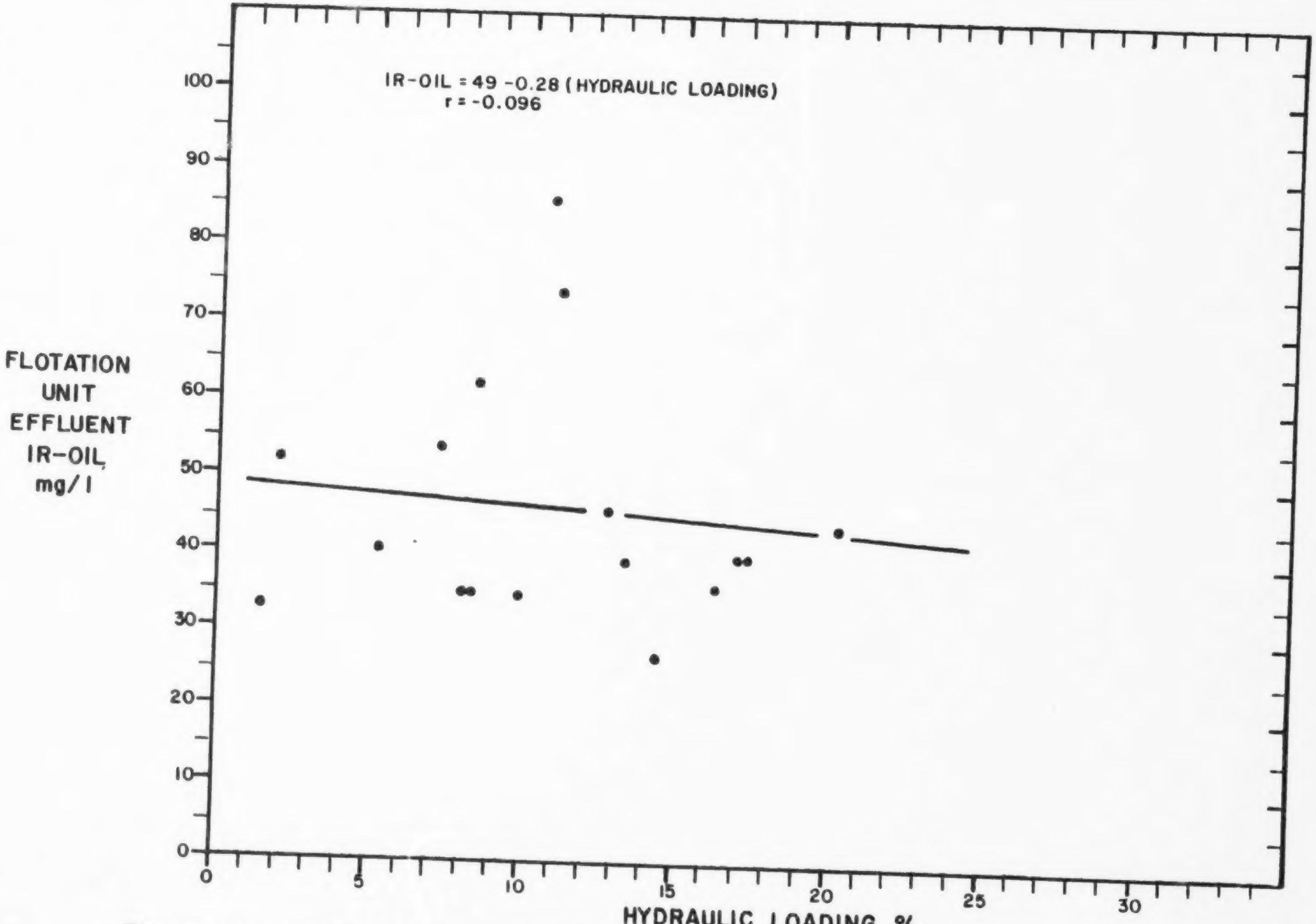


Figure 118. SM130B flotation unit hydraulic loading - infrared oil regression.

Gravity Separator Performance

The sample point for the gravity separator effluent is the same as for the flotation unit influent (9--i). The CPI effluent oil content data are presented in Table 181. The CPI effluent mean IR-Oil content was 156 mg/l.

The results of the susceptibility to separation tests on the CPI influent are presented in Table 189. The mean IR-Oil content after 30 minutes of settling was 155 mg/l. If the 155 mg/l is compared to the CPI effluent mean IR-Oil of 156 mg/l, it indicates that the CPIs are doing the equivalent of 30 minutes of static settling.

The largest oil drop detected by the particle size test in the oil treater effluent had a diameter of 120 µm.

Miscellaneous Brine Tests

All other brine test results for SM130B are listed in Tables 190, 191, and 192. The results for the following tests were generally in narrow ranges for all samples: temperature, pH, and specific gravity. These parameters were therefore not examined for correlation with sample-to-sample variation in effluent oil content. These parameters will be discussed in a later section with respect to variations between platforms.

Only one ionic analysis test and one sulfate reducing bacteria test per sample point were run on SM130B. These tests also are only significant with respect to comparisons between platforms.

Crude Oil Tests

All crude oil test results are listed in Tables 193 and 194. The crude oil temperature, specific gravity, and surface tension test results all fell in narrow ranges.

The viscosity and boiling range distribution tests were limited in number to one and are of primary significance for comparisons between platforms. Two equilibration tests were run, each at a different oil/water ratio. The extraction step was duplicated for each.

The limited number of tests run on crude oil provide only a limited characterization of the crude oil. Between-platform comparisons will be presented in Section 17.

TABLE 189. SM130B SUSCEPTIBILITY TO SEPARATION TESTS ON GRAVITY SEPARATOR INFLUENT

	Settling time, minutes							
	0	2	5	15	30	60	120	0
Test Number 1 Day 3, 1300								
IR-Oil, mg/l	261	174	166	157	153	126	109	270
IR-Oil W/Silica Gel, mg/l	205	-	92	-	-	-	39	-
Test Number 2 Day 4, 1300								
IR-Oil, mg/l	379	148	148	148	144	122	100	431
IR-Oil W/Silica Gel, mg/l	301	-	92	-	-	-	39	-
Test Number 3 Day 8, 1500								
IR-Oil, mg/l	597	218	192	174	168	135	113	527
IR-Oil W/Silica Gel, mg/l	532	-	157	-	-	-	78	-
Average								
IR-Oil, mg/l	412	180	169	160	155	128	107	409
IR-Oil W/Silica Gel, mg/l	346	-	114	-	-	-	52	-

TABLE 190. SM130B SUPPLEMENTARY BRINE TESTS

Sample time		Temperature, °C			pH	Specific gravity(1)
Day	Hour	8K-i	9--i	9--0	9--0	9--0
01	08	40.5	40.0	39.5	6.3	1.134
02	08	40.5	39.5	40.5	6.3	1.133
03	08	41.0	40.5	40.0	6.6	1.129
04	08	40.5	39.5	38.5	6.1	1.134
05	08	41.0	40.5	40.0	6.0	1.129
06	16	39.5	37.5	38.5	6.2	1.139
07	08	41.0	41.0	40.0	6.2	1.131
08	08	42.0	42.0	42.0	6.1	1.134
09	08	42.0	41.0	41.0	6.1	1.129
10	08	41.0	40.0	40.5	6.2	1.134
Mean		40.9	40.2	40.1	6.2	1.133
Minimum		39.5	37.5	38.5	6.0	1.129
Maximum		42.0	42.0	42.0	6.6	1.139

Note: Sample point identification numbers (8--i, 9--i, 9--0) as shown on flow diagrams.

(1) Specific gravity is reported at temperature shown in table above.

TABLE 191. SM130B SULFATE REDUCING BACTERIA

Sample point	Bacteria per milliliter
Wet Oil Tank - Bottom	10-100
Low Pressure Separator - Out (5--0)	10-100
Gravity Separator (CPI) - Bottom (8A-B)	10-100
Gravity Separator (CPI) - Bottom (8B-B)	1000-10,000
Flotation Unit - Out (9--0)	10-100

Sample Day and Hour: 05 at 17

TABLE 192. SM130B IONIC ANALYSIS FLOTATION UNIT EFFLUENT

Constituent	Concentration, mg/l
Sodium (Na)	53,325
Potassium (K)	340
Calcium (Ca)	3,560
Magnesium (Mg)	1,590
Barium (Ba)	160
Chloride (Cl)	104,000
Sulfate (SO_4)	< 5
Alkalinity (as HCO_3)	73
Iron (Total)	15
Sulfide (as H_2S)	0.15
Total Dissolved solids	
Summation	163,000
Gravimetric	163,000

Sample Day and Hour: 07 at 15

TABLE 193. SM130B CRUDE OIL MISCELLANEOUS TESTS(1)

Sample time Day	Hour	Temperature °C	Specific(2) gravity	Surface tension(3) dynes/cm
01	08	39.0	0.863	26
02	08	38.5	0.865	27
03	08	35.0	0.868	25
04	08	31.5	0.869	27
05	08	33.0	0.866	25
06		30.5	0.865	27
07	08	33.0	0.866	25
08	08	38.0	0.862	27
09	08	37.0	0.862	25
10	08	34.5	0.863	27
Mean		35.0	0.865	26
Minimum		30.5	0.862	25
Maximum		39.0	0.869	27

Sample time		Viscosity at 37.77°C	
Day	Hour	Kinematic centistokes	Absolute centipoise
07	15	7.87	6.92

	Equilibration at 82°C Brine TDS = 163,000 mg/l	
Oil/Water Ratio	4/1	4.4/1
IR-Oil, mg/l	98(85)	29(22)
IR-Oil W/Silica Gel, mg/l	8(3)	3(2)
IR-Oil Filtered Brine, mg/l	92(98)	31(31)

---

(1) Samples taken from outgoing pipeline.
(2) Specific gravity reported for temperature in table.
(3) Surface tension measured and reported at ambient temperatures from 23°C to 25.5°C.
( ) Duplicate extraction on same sample.

TABLE 194. SM130B CRUDE OIL BOILING RANGE DISTRIBUTION

	Run
Initial Boiling Point, °C	150
Final Boiling Point, °C	400

Boiling range, °C	Percent recovered
Below - 200	77.4
200 - 250	14.0
250 - 300	7.0
300 - 350	1.4
350 - 400	0.2
400 - 450	0.0
450 - 500	0.0
Total	100.0

SECTION 16

MEASUREMENT OF OIL DROP SIZE DISTRIBUTION

GENERAL

The purpose of this section is to present a summary of drop-size data considered most significant for correlation with effluent oil content.

Drop-size-distribution measurements from photomicrographs were made on the brine of nine of the ten survey platforms. The primary sampling points were the flotation unit influents and effluents. Some tests were run at points in the process system ahead of oil/water separators.

The drop-size measurements were made by a new technique developed for EPA by Rockwell International. A complete discussion of the technique will be found in a separate EPA report. The system has several unique facets that will be discussed briefly in this summary.

The plan called for three test runs involving a total of 400 water samples at each sample point. With a few exceptions, this was accomplished. Brine samples of the photomicrographic test unit effluent were taken for oil content testing during Phase II only. These results were taken for comparison with calculated, dispersed oil contents from the drop-count measurements.

A nominal 20,000 photomicrographs were taken of 10,000 brine samples. The data were reduced to size-number tabulations and histograms, size-concentration tabulations and histograms, cumulative size-number probability plots, and cumulative size-concentration probability plots. However, only summary tabulations of cumulative percent-by-number, cumulative percent-by-weight/volume of calculated oil, and assigned oil content versus drop diameter are presented here.

DROP SIZE MEASUREMENT TEST PROCEDURE

A diagram of the drop-size test system is presented in Figure 119. Sampling of the pipeline flow, pressure reduction, and bypass sampling were combined to deliver a fresh turbulent flow dispersed sample to the microscope cell. Bypass sampling and pressure reduction were accomplished with an overflow standpipe technique. Whenever possible, the overflow of the standpipe was maintained at several times the sample cell flowrate. This insured that a fresh, well-dispersed sample was available whenever the sample cell flow-control solenoid valve permitted flow. Flow through the microscope cell during purging was sufficient to replace the cell liquid with a fresh sample

EPA-287 (Cin.)
(4-76)

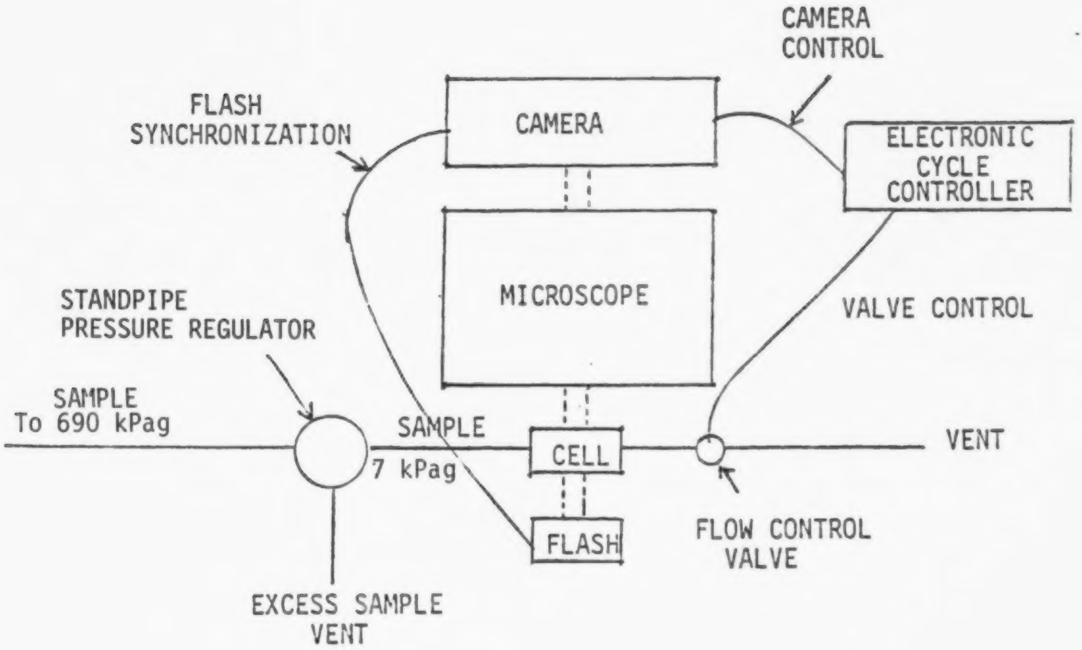

CAMERA CONTROL
FLASH SYNCHRONIZATION
CAMERA
ELECTRONIC CYCLE CONTROLLER
MICROSCOPE
STANDPIPE PRESSURE REGULATOR
VALVE CONTROL
SAMPLE To 690 kPag
SAMPLE 7 kPag
CELL
VENT
FLASH
FLOW CONTROL VALVE
EXCESS SAMPLE VENT

Figure 119. System Diagram

of the flowing liquid in the standpipe. The microscope optics were selected to produce a nominal photographic magnification of 150X. A 35-mm camera equipped with a 250-exposure back and motor drive was connected to the microscope with an adapter. Apparent drop movement during photography was eliminated by the use of a shorter than 5-microsecond-duration electronic flash illuminator.

A more complete description of the system may be found in the previously cited work.

One of the unique attributes of the system is its ability to measure the density of the photographed objects as well as their size. Thus the system can differentiate between oil drops, gas bubbles, and sand grains. This is achieved by locating the viewing axis of the microscope in the horizontal plane rather than the more common vertical plane. Since the movement of the photographed objects due to the effect of gravity is vertical, they now move across the viewing plane of the microscope and across the photographic film. Time-lapse photography allows measurement of the speed and direction of this movement. Application of Stokes' law principles permits the calculation of the density of the object.

The density measurement capability requires interruption of the sample flow. In fact, the sample must be stationary for several seconds to allow the turbulence currents to dissipate and movement by gravity to predominate.

The microscope was focused near the top of the cell to detect oil drops that are lighter than produced brine. This allows the maximum rise distance before the drop escapes the opportunity to be photographed. Calculations based on Stokes' law indicate that an approximately 115 μm drop originally located at the bottom of the cell will not have escaped the photography zone during the established time cycle of 10 seconds static period and 2 seconds of photography.

Sample withdrawal from the pipeline and transport to the system fills the cell with uniformly dispersed sample and each micro volume has the same chance of containing drops of any size. Therefore, although the various-size drops captured in a photograph were originally in different locations within the cell, no bias is introduced.

Generally, brine test samples were taken from flowing streams in pipes at pressures less than 60 kPag (10 psig). Sample points were either globe or ball valves that would accept adaptors for 1.25-cm-diameter Eastman Imperial Poly-Flo tubing. These valves were always in the full-open position during test runs. The Poly-Flo tubing was kept to a minimum length, consistent with space and safety considerations. The Poly-Flo tubing was connected to a standpipe that maintained a uniform low pressure of about 7 kPag for feeding the brine to the photographic cell. Exceptions for individual sample points are noted in the following paragraphs.

The standard test sequence for each platform required runs at three sample points; the input and output of the final water treatment unit, and the first water knockout tank input. The typical photographic cycle at each sample point included 160 time-lapse triads and 250 single photographs. In total, 410 individual water samples were examined at each sample point.

High-oil-content samples such as the feed to the separators were subjected to a preliminary separation to remove the drops larger than 100 micrometers before passing into the microscope cell. The maximum possible drop size in the sample is dependent upon the pre-settling time, the fluid parameters, and position in the sampling cycle. The size cutoff is approximately 40 μm at the fifth water sample and 60 μm at the twentieth water sample.

The size and x-y location of the drops in each photograph of a time-lapse triad were determined by projection of the color transparency on a digitizing platen. An operator manually touched the platen stylus to the sides of each drop. The data were stored in computer files for calculation of density, drop-size distribution, log-normal cumulative drop-size distribution, oil content in mg/l, etc. Calculated dispersed oil content was based on the volume of the oil drop and the liquid volume photographed. The cross-section of this volume was 356 plus the drop diameter by 535 plus the drop-diameter micrometers, as defined by the photographic film aperture and the thickness by the depth of focus of the microscope optics. The system was calibrated with stage micrometer photographs and the depth of focus determined from photographs of gel-suspended oil drops. The apparent depth of focus and therefore the liquid volume photographed was dependent upon drop diameter.

The percent-by-number and percent-by-weight/volume data are all based on a normalized liquid volume photographed.

SAMPLE POINTS

Only the flotation influent and effluent samples are discussed. In all cases, the best available sample point was used.

Platform SP65B

Platform SP65B is the only one of which particle size measurements were not obtained. Photomicrographs were not obtained on this first platform due to improper microscope focus.

Platform WD45C

Separate tests on uncombined streams from the "A" and "B" gun barrels were used to represent the flotation unit influent. The samples were taken from tees in 10-cm (4-inch) water legs. The sampling pressure was less than 69 kPag.

The flotation effluent sample point was on the side of the flotation unit near the outlet. The pressure was less than 20 kPag.

Platform ST177

The flotation influent and effluent samples were taken from the side of horizontal 20-cm (8-inch) lines. The pressures at both points were less than 12 kPag.

Special sampling experiments were conducted by inserting probes to the center of the lines to determine if probes were needed to obtain representative samples. The results did not indicate that the probes were necessary.

Platform BM2C

The flotation influent sample point was on a vertical run of 20-cm (8-inch) pipe at a point where there was free fall of the flow. It was necessary to pinch a downstream valve to obtain a sample.

The flotation effluent sample point was on a 20-cm (8-inch) elbow. The estimated pressure was 7 kPag.

Platform ST131

The flotation influent sample point was on a 15-cm (6-inch) vertical standpipe. The pressure was about 55 kPag.

The flotation effluent sample was obtained by siphoning from the effluent settling chamber to a lower deck. Fifteen meters of garden hose and 2.5 meters of Poly-Flo tubing were used.

Platform BDCCF5

The flotation effluent sample tap was on the side of a 20-cm (8-Inch) horizontal line 0.3 meter from the tank wall and 2 meters below the fluid level. The pressure was about 18 kPag.

Tests on influent samples were not completed. The film failed to advance. The sprocket holes were stripped for no apparent reason.

Platform SS107

Both the flotation influent and effluent sample points were on the top side of the 20-cm (8-inch) horizontal pipes 0.3 meter from the tank wall and 0.5 meter below the fluid level. The estimated pressures were 5 kPag.

Platform SS198G

The flotation effluent sample point (Tridair, 9-10) was on the top of a horizontal 10-cm (4-inch) pipe. The estimated pressure was 45 kPag.

The flotation influent sample point (Tridair, 9-1i) was on the side of a horizontal 10-cm (4-inch) pipe. The estimated pressure was 4 kPag.

Platform EI18CF

The flotation effluent sample point was on the underside of the flotation unit effluent launder. The estimated pressure was less than 3 kPag.

The flotation influent sample point was at the gravity separator outlet. A 2.5-cm-diameter probe was inserted 2 meters into a 45-cm (18-inch) horizontal line for sampling ahead of the pump. The estimated pressure was 50 kPag.

Platform SM130B

The flotation effluent sample point was on the side of a horizontal 20-cm (8-inch) line ahead of the unit level control valve which was located on the deck below the flotation unit. The estimated pressure was 100 kPag

The flotation influent sample point was in a 20-cm (8-inch) elbow that went from horizontal to vertical just ahead of and above the flotation unit. The pipe was not full at the sample point. A 1.25-cm probe was inserted into the horizontal run of pipe to obtain samples. There was essentially no pressure at the sample point.

PURPOSE OF TESTS

The photomicrographic studies were performed to determine the oil-drop-size distribution at several points in the produced brine treatment system. The two classes of water treating units surveyed in this program were gravity separators and flotation units. Stokes' law is generally applied in gravity separator design for removal of all oil drops above a certain diameter. Onehundred-fifty micrometers (μm) is used in designing API separators. Any drop size can be selected and 60 μm is a relatively common criterion for proprietary separators. The CPI units on the platforms studied were designed to remove drops above 30 to 40 μm. Thus, knowledge of the drop-size distribution in the gravity separator effluents may be used to evaluate their performance during routine field operation. Since the separator effluent is the flotation unit influent, measurements were made at the flotation unit influent. Additional "high oil" measurements were made at the separator influent to gather data on the small-drop population in the separator feed stock.

Manufacturers frequently claim oil reductions to less than 10 mg/l with gravity separation equipment. However, removing all oil drops of a certain size does not necessarily ensure a certain oil content. It is therefore informative to compare separator performance in terms of measured oil content and maximum-size drop present.

Each platform in the survey had a flotation unit to provide the final treatment step. These flotation units have the potential for altering the drop-size distribution toward smaller drops by the shear of pumps or mechanical eductors. A study of the drop-size distribution in the influent and effluent of the flotation units may be used to better define this action and evaluate effectiveness of the several flotation units.

Mechanically formed oil dispersions in water are often electrostatically stabilized. Polyelectrolyte chemicals were added to most of the flotation units studied to destabilize the dispersions. The intended purpose of these chemicals is to reduce the effect of small-drop dispersions on the effluent. The effectiveness of this treatment may also be evaluated by this study.

DATA PRESENTATION AND EVALUATION

Sixty-nine drop-size-measurement runs were made on nine different platforms. A complete tabulation of drop counts by drop size is presented for each run in Table 195 and Table 196. Table 197 presents run identification numbers by platform and sample point for Phase I runs. Table 198 presents the same information for Phase II runs. Table 195 presents Phase I drop counts and Table 196 presents Phase II drops counts identified by the run numbers in Tables 197 and 198.

Tables 199 through 202 summarize the results for the flotation unit influents and effluents by combining all data obtained at each sample point. Table 199 presents cumulative percent-by-number distribution and Table 200 presents cumulative percent-by-weight/volume oil content calculated from drop-size tests. In both cases, the dependence of the photographed volume on drop diameter has been included in the calculation to normalize the values to a common sample volume. Table 201 presents cumulative oil concentrations based on the total oil contents measured by, the IR-Oil w/Silica Gel method and the percent weight/volume calculated oil contents from the drop-size-distribution studies.

A comparison of the total oil content as calculated from the drop-size distribution and the values measured by the IR-Silica Gel method shows that

TABLE 195. PHASE I DROP SIZE DATA

Run:	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	1	2	3	4	5	6
Size, µm																												
1	21	41	3	1	5	1	11	17	7	15	18	16	25	45	10	15	12	10	26	32	67	30	10	84	37	36	129	73
2	208	147	24	48	59	59	82	109	129	77	151	103	184	286	86	97	121	104	77	183	181	194	190	651	304	181	558	485
3	520	301	180	193	314	185	137	99	79	75	89	67	222	431	134	171	142	86	97	188	150	209	872	546	447	183	547	630
4	310	174	191	137	177	90	62	22	12	19	12	17	106	134	68	66	57	20	22	35	34	66	595	144	191	42	135	233
5	193	67	104	69	79	53	28	9	7	8	9	5	50	64	48	32	28	4	14	22	11	29	305	66	108	18	62	126
6	122	46	46	48	52	22	19	1	5	4	6	4	18	37	18	20	17	6	5	10	11	13	178	39	55	11	34	66
7	66	33	32	30	35	19	6	5		1	3		13	17	9	10	10	2	5	5	14	8	116	15	29	7	27	36
8	64	28	22	11	24	20	6			1	2		12	12	11	3	4			6	5	10	77	9	18		21	18
9	34	10	20	18	14	10	2	1		1		2	6	2	5	6	2	2	2	5	4	1	62	6	13	4	10	17
10	26	9	6	6	6	4	4	2			1		5	3	2	6	1	2	1	2	6	1	22	7	9	3	.9	12
11	23	12	4	4	8	2	1						1	2	4	3				2	3	2	18	1	7		7	7
12	11	5	5	4	2	1				2	1		1	1			2			1	2	1	12	3	2		4	2
13	12	3	4	4	2	3	2	1		2			1		1	2				2	2		13	5	3		4	3
14	7	3	3	3	5	5				1	1		1	1	1				1	3	2	4	16	2	1	1	9	2
15	6	1	1		1	1	1						0	1						2	1	1	3	1			4	
16	7	2	2	4	2		1						1								1	3	8	1			4	
17	4	1	2	6	1	1							1	1	1					2	3	2	10		1		7	1
18	2	2		1	1				1														2	1			6	
19	1	3	2	4	3	1								1	1	1				3			10		2		3	2
20	6	2	1	1		1														2	3	5	3				10	
21	2	1		3	2	1	2														1	2	6	2			3	
22						3																1	4				1	
23	2					1							1								2	1	1				3	
24	1	1	1											1						1	1	1	1				3	
25			1	3												2				1	2		4		2		3	2
26	1		1	1	1																		3					
27			1	1	1																		3					
28	1	1	1																	1	1	3	1				5	
29				1																	1	3	1				4	
30		1			1		1														2	1	1	1			3	
31					1		1													1			1	1			1	
32	1			1																		1	1				1	
33		2																										
34			1	1																1		1	2				2	
35																												
36																				1		2					3	
37																				1	1	1					3	
38		1		1																			1					
39																				1	1	1					3	
40					2															1			2				1	
41					1															1	1		1				2	
42										1														1				
43					1																		1					
44																												
45																												
46																						1					1	
47																												
48																												
49																						1					1	
50																												
				xxx																	xxx	xxx	xxx				xxx	

xxx Run 1, 55, 1
xxx Run 5, 51, 2; 52, 1; 64, 1
xxx Run 104, 55, 1
xxx Run 121, 51, 1
xxx Run 122, 51, 1; 52, 1; 64, 1

TABLE 196. PHASE II DROP SIZE DATA

Run:	81	91	82	92	31	32	33	34	35	37	83	93	41	42	43	44	45	47	84	94	51	52	53	54	55	56
Size, µm																										
1					1	1	1			4	3				6			4	6				2			1
2	1				8	12	2			1	22		6	1	3		1	12	10	1			12			12
3					34	34	33	1		3	101	1	72	15	29		5	68	116	5		3	53		1	29
4		4	1		36	49	38	1		8	123	1	54	23	74	5	3	107	151	8	2	20	31	6	2	38
5	2	4	2	3	88	99	63		1	14	250	1	90	58	67	10	3	153	215	13	7	39	52	14	6	54
6	4	3	1	3	83	106	77	2		18	266	2	60	51	112	4	4	138	223	8	13	17	33	10	5	57
7	1	5	7	3	66	75	73	1		36	214	1	39	39	80	5	1	101	158	6	7	18	31	4	3	31
8	9	6	5	4	51	54	78			20	183		23	18	45	1		63	86	1	7	16	36	8	3	27
9	2	3	5	5	33	31	42	1	1	16	106	2	20	11	33	1		51	64	1	12	13	30	4	8	21
10	4	1	3	4	20	21	32	1	2	16	73	3	6	5	10			28	21		7	12	12	4	5	10
11	2	2	1	2	13	17	21	1		10	51	1	9	5	9	1	1	21	23	2	8	8	6	3	4	6
12					8		11			8	19		1	1	5	2		19	7	2	6	9	7	3	1	7
13				1	7	9	13	1		8	29	1	4	2	7			17	13		3	4	11	1		10
14		2	1		3	4	6			5	13		1	1	2			11	4		2	1	8	2	2	8
15					1	2	4			1	7		1					9	1		1	1	10		3	6
16					2	5	6		1	2	13	1		1				4	1		2	2	3	2	1	6
17	1			1	3	2	11			2	16			1	2			5	3		4	1	5	1		7
18					5	1	6			5	12		1					9	1		4	2	3			7
19						2	3			1	5				1			6	1		2		2	2		4
20					2	1	3			1	6				1				1			1	4	1	2	3
21		1		1						2								1			2	1	3	1		
22				1	1		3				4			1	1			1	2				2		2	1
23							2				2							3				2	3		2	2
24							3				3											2	1			2
25						1	1			2	2		1					1	1				2			1
26						1	1			2	2												1	1	1	1
27							1			4	1							1							1	1
28					1						1				1				1							
29						1	3			1	4							2								2
30										1								1			2	2				
31																		1								1
32							1				1							1				1				1
33					1	1					2													1		
34					1						1															1
35		1		1													1			1				1		1
36							1				1															
37																		1								
38																									1	
39																										1
40																		1								
41										1														1		1
42																										1
43																										
44										1																
45																										1
46																								1		1
47																										
48																										
49							1			1	1															
50																										
										xxx								xxx						xxx	xxx	xxx

xxx Run 37, 66, 1;87, 1
xxx Run 47, 54, 1
xxx Run 54, 56, 1
xxx Run 55, 65, 1; 58, 1
xxx Run 56, 89, 1; 97, 1

(continued)

TABLE 196. (Continued)

Run:	57	85	95	61	62	63	86	71	72	73	74	76	77	87	97
Size, µm															
1	2	2	1	6			6		1		1	3	1	1	4
2	5	12	12	66	19		85	7	4	27	15	60	5	38	75
3	38	56	30	81	87	1	169	23	63	112	48	73	23	198	121
4	26	53	46	46	58	1	105	21	66	97	36	54	41	184	90
5	40	98	74	40	48	2	90	26	79	104	11	34	68	209	45
6	12	63	72	15	17	4	36	15	80	57	7	14	60	152	21
7	8	56	38	10	13	8	31	7	51	45	3	6	46	103	9
8	10	59	38	7	5	2	14	10	47	24		2	30	81	2
9	7	55	33	2	3	3	8	4	30	14		1	24	48	1
10	1	31	19	1	4		5	2	15	14			15	31	
11	3	22	13	3	1		4	1	14	14			6	29	
12		22	11	2		2	4	1	7	6			7	14	
13	2	18	11	1	1	1	3		6	4			6	10	
14	1	11	12			1	1	1	8	10	1		4	19	1
15		12	9					1	3	8			3	12	
16	1	7	9					1	3	5			1	9	
17	1	10	8						2	4			3	6	
18		9	7						2	1			1	3	
19	1	4	6						2	3			1	5	
20		5	6						2	3			1	5	
21		6	1		1		1						2		
22		2	3												
23		5	4												
24		3	2			1	1		3	1			1	4	
25		2	1							1			1	1	
26		1	3							1			1	1	
27			2						1	2			1	3	
28										2				2	
29			2						1	2				3	
30		4							1					1	
31			1						1					1	
32		1	1	1			1		1	3				4	
33			1						1	3				4	
34			1						2	2				4	
35			2							2				2	
36										2				2	
37															
38			1							1				1	
39			1												
40													1		
41			2												
42			1												
43										1				1	
44										1				1	
45			1							1				1	
46			2						1					1	
47													1		
48									1	1		1		2	2
49								1	1					2	
50										1				1	
			xxx			xxx	xxx		xxx	xxx		xxx	xxx	xxx	xxx

xxx Run 95, 55, 1; 56, 1; 58, 1; 89, 1; 97, 1
xxx Run 63, 81, 1
xxx Run 86, 81, 1
xxx Run 72, 51, 1; 67, 1; 69, 1; 85, 1; 90, 1; 100, 1; 112, 1; 118, 1
xxx Run 73, 52, 1; 55, 1; 56, 1; 58, 1; 59, 1; 61, 3; 63, 1; 65, 1; 66, 1; 69, 1; 71, 1; 72, 1; 75, 1; 77, 1; 78, 1; 85, 1; 102, 2; 111, 1; 112, 1; 114, 1; 120, 1
xxx Run 76, 59, 1
xxx Run 77, 67, 1; 83, 1; 88, 1
xxx Run 87, 51, 1; 52, 1; 55, 1; 56, 1; 58, 1; 59, 1; 61, 3; 63, 1; 65, 1; 66, 1; 67, 1; 69, 2: 71, 1; 72, 1; 75, 1; 77, 1; 78, 1; 85, 2; 90, 1; 100, 1; 102, 2; 111, 1; 112, 2; 114, 1; 118, 1; 120, 1
xxx Run 97, 59, 1

TABLE 197. PHASE I DROP SIZE RUN IDENTIFICATION

Run	Platform	Samples	Drops	Oil(1) mg/l	Sample point
101	ST177	90	1,651	501	High oil - gun barrel inlet
102		46	897	538	High oil - gun barrel inlet
103		86	606	366	Wemco inlet pipe center sample
104		81	658	256	Wemco inlet pipe center sample
105		87	810	337	Wemco inlet pipe wall sample
106		84	483	147	Wemco inlet pipe wall sample
107		83	366	94	Wemco outlet pipe center sample
108		85	266	21	Wemco outlet pipe center sample
109		85	240	16	Wemco outlet pipe center sample
110		87	207	48	Wemco outlet pipe wall sample
111		83	293	22	Wemco outlet wall sample
112		85	214	12	Wemco outlet pipe wall sample
113	WD45C	71	1,039	150	High oil - "A" inlet sample
114		87	650	103	High oil - "A" inlet sample
115		83	396	46	"B" outlet stream to Monosep
116		83	434	88	"B" outlet stream to Monosep
117		88	399	70	"B" outlet stream to Monosep
118		82	250	24	"A" outlet stream to Monosep
119		60	236	26	"A" outlet stream to Monosep
120		77	604	649	Monosep output (upset condition)
121		89	517	309	Monosep output (upset condition)
122		86	516	279	Monosep output (upset condition)
01	ST177	340	2,557	277	Combined Wemco input runs
02		512	1,586	35	Combined Wemco output runs
03	WD45C	256	1,229	68	Combined "B" stream to Monosep
04		143	486	25	Combined "A" stream to Monosep
05		254	1,637	406	Combined Monosep output runs
06		399	1,715	53	Combined Monosep input runs

(1) Oil as calculated from drop counts.

only four of the calculated values were less than the measured values while 12 were higher. A simple calculation indicates that the calculated values averaged 3 times the measured values. The largest disparities resulted from samples having either a small number of counted drops or several large drops. Either of these can seriously distort the calculated oil values since the oil drop population is statistically small. The measured IR-oil technique samples 3×10^5 times the photographed volume and the statistical distribution becomes more effective.

Gravity Separator Effluent

During Phase II of the survey, drop-size tests were run on the gravity separator effluents of six platforms. IR-Oil content and dispersed oil content were determined analytically on the effluent from the drop-size test runs. Summary listings of the median drop, the largest drop, the IR-Oil content and the dispersed oil content are presented in Table 202.

The median sized drops for the six platforms had diameters in the range from 4 μm to 7.5 μm. There is not a clear relationship between median-drop size and measured oil content.

The largest drops in the six effluents were in the range from 28 to 120 μm. There was no apparent relationship between the largest drop present

TABLE 198. PHASE II DROP SIZE RUN IDENTIFICATION

Run	Platform	Samples	Drops	Oil[1] mg/l	Dispersed oil[2] mg/l	Sample point
81	BM2C	410	26	4	9	Combined Wemco output
91		410	32	9	42	Combined Wemco input
82	SS107	410	26	4	1	Combined Wemco output
92		410	29	11	99	Combined Wemco input
31	ST131	79	468	339	168	Wemco input
32		81	529	338	243	Wemco input
33		199	540	257	201	Wemco input
34		82	9	7	10	Wemco output
35		75	5	7	2	Wemco output
37		159	196	298	726	High oil sample
83		359	1,537	293	204	Combined Wemco input
93		157	14	7	5	Combined Wemco output
41	SS198G	91	388	133	84	Tridair input
42		77	233	113	34	Tridair input
43		210	489	95	8	Tridair output
44		76	29	14	0	Tridair output
45		39	19	49	0	Tridair output
47		267	841	222	139	High oil sample
84		378	1,109	108	51	Combined tridair input
94		115	48	26	3	Combined tridair output
51	EI18CF	54	91	227	74	Flotation output
52		79	175	205	78	Flotation output
53		222	363	129	82	Flotation output
54		57	72	313	94	Flotation input
55		64	55	282	245	Flotation input
56		244	365	278	229	Flotation input
57		23	158	200	199	High oil sample
85		355	629	161	78	Combined flotation output
95		365	492	284	189	Combined flotation input
61	BDCCF5	82	281	66	43	Monosep output
62		79	257	59	20	Monosep output
63		207	27	53	21	Monosep output
86		368	565	57	28	Combined Monosep output
71	SM130B	77	121	87	78	Wemco input
72		258	507	484	65	Wemco input
73		234	603	1,093	122	Wemco input
74		77	122	18	16	Wemco output
76		216	250	62	14	Wemco output
77		234	357	218	249	High oil sample
87		574	1,231	685	88	Combined Wemco input
97		293	372	50	15	Combined Wemco output

(1) Oil as calculated by drop counts.
(2) Dispersed oil as determined by IR-Oil w/Silica Gel tests.

and measured oil content, though large drops contribute significantly.

All oil drops larger than 50 μm were effectively removed by four of the six gravity separators. None of the measured IR-Oil contents were as low as 100 mg/l with the lowest being 127 mg/l.

For most platforms the same sample point represented the gravity separator effluent and the flotation influent. Additional discussion of flotation influents (gravity separator effluents) is presented in the next subsection.

Flotation Unit Influents and Effluents

Previously referenced Table 199, Table 200, and Table 201 present drop-size-number distributions and drop-size oil-concentration distributions for flotation unit influents and effluents. The drop-size range covered is from

TABLE 199. CUMULATIVE PERCENT-BY-NUMBER DROP SIZE DISTRIBUTION FOR COMPOSITES OF TEST RUNS

Platform	Samples(1)	Number of drops	Oil		Percent-by-number of drops with diameter equal or less than									Large drops		Largest drop
			Calculated(2) mg/l	Measured(3) mg/l	2 µm %	5 µm %	10 µm %	20 µm %	30 µm %	40 µm %	60 µm %	100 µm %	>100 µm %	>40	>60	µ
Flotation Influent																
WD45C	399	1,715	53	-	44.5	94.2	99.6	99.97	100.00	-	-	-	-	0	0	25
ST177	340	2,557	277	-	13.0	85.5	98.0	99.5	99.92	99.97	100.00	-	-	3	0	55
BM2C	410	32	9	42	0.01	32.5	89.0	97.3	99.0	100.00	-	-	-	0	0	35
ST131	359	1,537	293	204	3.8	41.0	92.5	99.4	99.88	99.98	100.00	-	-	1	0	49
BDCCF5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS107	410	29	11	99	0.01	32.8	89.0	97.2	99.0	100.00	-	-	-	0	0	35
SS198G	378	1,109	108	51	3.8	54.0	97.0	99.87	100.00	-	-	-	-	0	0	28
EI18CF	365	492	284	189	6.3	45.0	85.6	97.3	99.0	99.55	99.95	100.00	-	11	2	97
SM130B	574	1,231	685	88	6.2	64.0	93.8	98.65	99.05	99.5	99.77	99.94	100.00	41	26	120
Flotation effluent																
WD45C	254	1,637	407(4)	-	57	95.2	98.2	99.4	99.8	99.95	99.95	100.00	-	8	1	64
ST177	512	1,586	35	-	57	97.1	99.63	99.94	99.98	99.98	100.00	-	-	1	0	41
BM2C	410	26	4	9	9	18	91	100.00	-	-	-	-	-	0	0	17
ST131	157	14	7	5	0.01	32.5	85.0	100.00	-	-	-	-	-	0	0	16
BDCCF5	368	565	57	28	25.2	87.8	98.8	99.85	99.94	99.98	99.98	100.00	-	1	1	81
SS107	410	26	4	1	0.01	15.0	93.5	100.00	-	-	-	-	-	0	0	14
SS198G	115	48	26	3	4.0	64.0	94.8	99.42	99.42	100.00	-	-	-	0	0	35
EI18CF	355	629	161	78	5.6	48.0	86.0	98.45	99.9	100.00	-	-	-	0	0	32
SM130B	293	372	50	15	30.3	94.2	99.78	99.78	99.78	99.78	100.00	-	-	3	0	59

(1) Number of brine samples photographed for drop counts.
(2) Oil as calculated from drop counts.
(3) Dispersed oil as measured by IR-Oil w/Silica Gel tests on the brine effluent from particle-size test equipment when the particle-size-distribution test was run.
(4) Test run during upset conditions.

TABLE 200. CUMULATIVE OIL CONTENT BY DROP SIZE IN PERCENT

			Oil		Percent of oil in drops with diameters equal or less than(2)									Large drops		Largest drop
Platform	Samples(1)	Number of drops	Calculated(2) mg/l	Measured(3) mg/l	2 µm %	5 µm %	10 µm %	20 µm %	30 µm %	40 µm %	60 µm %	100 µm %	>100 µm %	>40	>60	µ
Flotation Influent																
WD45C	399	1,715	53	-	5	44.5	76	92.5	100.00	-	-	-	-	0	0	25
ST177	340	2,557	277	-	0.42	17.5	37.5	60	79	91	100.00	-	-	3	0	55
BM2C	410	32	9	42	0.01	3.0	27.5	46.0	57.0	100.00	-	-	-	0	0	35
ST131	359	1,537	293	204	0.03	6.0	42.8	76.2	90.0	97.0	100.00	-	-	1	0	49
BDCCF5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS107	410	29	11	99	0.01	3.0	26.0	43.0	65.2	100.00	-	-	-	0	0	35
SS198G	378	1,109	108	51	0.06	14.5	70.8	93.0	100.00	-	-	-	-	0	0	28
EI18CF	365	492	284	189	0.02	1.9	10.8	31.0	43.0	56.0	79.5	100.00	-	11	2	97
SM130B	574	1,231	685	88	0.02	1.7	6.8	12.4	15.5	22.8	37.0	65.5	100.00	41	26	120
Flotation Effluent																
WD45C	254	1,637	407(4)	-	1.3	6.6	11.5	27.2	48.8	74.0	94.3	100.00	-	8	1	64
ST177	512	1,586	35	-	7.3	37	55	70	80	87	100.00	-	-	1	0	41
BM2C	410	26	4	9	0.12	2.0	67.0	100.00	-	-	-	-	-	0	0	17
ST131	157	14	7	5	0.01	3.0	48.5	100.00	-	-	-	-	-	0	0	16
BDCCF5	368	565	57	28	0.85	17.4	37.5	46.3	51.5	58.0	58.0	100.00	-	1	1	81
SS107	410	26	4	1	0.01	2.8	80.0	100.00	-	-	-	-	-	0	0	14
SS198G	115	48	26	3	0.07	11.4	31.0	47.0	47.0	100.00	-	-	-	0	0	35
EI18CF	355	629	161	78	0.04	4.2	27.5	71.0	97.8	100.00	-	-	-	0	0	32
SM130B	293	372	50	15	1.1	17.5	24.8	26.0	26.0	26.0	100.00	-	-	3	0	59

(1) Number of brine samples photographed for drop counts.
(2) Oil as calculated from drop counts in milligrams per liter.
(3) Dispersed oil as measured by IR-Oil w/Silica Gel tests on the brine effluent from the particle-size test equipment when the particle-size-distribution test was run.
(4) Test run during upset conditions.

TABLE 201. CUMULATIVE ASSIGNED OIL CONTENT DISTRIBUTION BY DROP SIZE GROUPS IN COMPOSITES OF TEST RUNS(1)

			Oil		Assigned concentration of oil in drops w/dia equal or less than (1)									Large drops		Largest drop
Platform	Samples(2)	Number of drops	Calculated(3) mg/l	Measured(4) mg/l	2 µm mg/l	5 µm mg/l	10 µm mg/l	20 µm mg/l	30 µm mg/l	40 µm mg/l	60 µm mg/l	100 µm mg/l	100 µm mg/l	>40	>60	µ
Flotation Influent																
WD45C	399	1,715	53	-	-	-	-	-	-	-	-	-	-	0	0	25
ST177	340	2,557	277	-	-	-	-	-	-	-	-	-	-	3	0	55
BM2C	410	32	9	42	0.0	1.3	11.6	19.3	23.9	42.0	-	-	-	0	0	35
ST131	359	1,537	293	204	0.1	12.2	87.3	155.4	183.6	197.9	204.0	-	-	1	0	49
BDCCF5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS107	410	29	11	99	0.0	3.0	25.7	42.6	64.5	99.0	-	-	-	0	0	35
SS198G	378	1,109	108	51	0.0	7.4	36.1	47.4	51.0	-	-	-	-	0	0	29
EI18CF	365	492	284	189	0.0	3.6	20.4	58.6	81.3	105.8	150.3	189.0	-	11	2	97
SM130B	574	1,231	685	88	0.0	1.5	6.0	10.9	13.6	20.1	32.6	57.6	88.0	41	26	120
Flotation Effluent																
WD45C	254	1,637	407(5)	-	-	-	-	-	-	-	-	-	-	8	1	64
ST177	512	1,586	35	-	-	-	-	-	-	-	-	-	-	1	0	41
BM2C	410	26	4	9	0.0	0.2	6.0	9.0	-	-	-	-	-	0	0	17
ST131	157	14	7	5	0.0	0.2	2.4	5.0	-	-	-	-	-	0	0	16
BDCCF5	368	565	57	28	0.2	4.9	10.5	13.0	14.4	16.2	16.2	28.0	-	1	1	81
SS107	410	26	4	1	0.0	0.0	0.8	1.0	-	-	-	-	-	0	0	14
SS198G	115	48	26	3	0.0	0.3	0.9	1.4	1.4	3.0	-	-	-	0	0	35
EI18CF	355	629	161	78	0.0	3.3	21.5	55.4	76.3	78.0	-	-	-	0	0	32
SM130B	293	372	50	15	0.2	2.6	3.7	3.9	3.9	3.9	15.0	-	-	3	0	59

(1) The cumulative oil concentration data in this table were calculated by multiplying the total analytically determined dispersed oil concentration by the percentage concentration data reported in Table 200.

(2) Number of brine samples photographed for drop counts.

(3) Oil as calculated from drop counts.

(4) Dispersed oil as measured by IR-Oil w/Silica Gel tests on the brine effluent from the particle-size test equipment when the particle-size-distribution test was run.

(5) Test run during upset condition.

TABLE 202. GRAVITY SEPARATOR EFFLUENT DROP SIZE-OIL CONTENT COMPARISON

Platform	Gravity separator type	Drop diameters		Oil content(2)	
		Median µm	Largest µm	IR-Oil mg/l	Dispersed oil mg/l
BM2C	Corrugated plate	6	35	131	42
SS198G	Corrugated plate	4.5	28	127	51
SM130B	Corrugated plate	4	120	138	88
ST131	Gun barrel	5.5	49	285	204
EI18CF	Skim tank	5	97	219	189
SS107	Oil treater(1)	7.5	35	153	99

(1) This separator was not specifically a water treatment separator, but was a dual purpose unit for removing water from crude oil.
(2) Oil contents are based on an average of three test runs measured on the effluent from the particle size test runs.

2 to 120 μm. The largest drop detected had a diameter of 120 μm. The cumulative number distribution data are presented in percent for listed μm sizes in Table 199 to permit comparison between platforms. The cumulative concentrations in Table 200 are also in percent for ready comparison.

The cumulative concentration data in Table 201 are presented in milligrams per liter since the amount of oil present in small drops is the most important question to consider. The concentration data in Table 201 are based on two assumptions. First, that the best available data on total dispersed oil content are those from the IR-Oil w/Silica Gel tests and second, that the best available data on drop-size distribution are those from the drop-size tests.

Table 203 presents an overall drop-size oil-concentration distribution summary. This table presents median drop sizes, total dispersed oil concentrations, and cumulative number and concentrations listings for 10-μm and 20-μm oil drops. The 20-μm comparison point was chosen because in flotation effluents 98 to 100 percent of all drops had diameters equal or less than 20-μm, and in flotation influents 97 to 99 percent of all drops had diameters equal or less than 20 μm. The 10-μm point was chosen because it is between the 20-μm point and the median drop size for all test runs. The following discussion is in reference to Table 203.

The median drop sizes for flotation influents were from 2 to 7.5 μm. The range for effluents was from 1.5 to 7 μm. The maximum difference for any platform in median drop size between the influent and the effluent was less than 2 μm. Median drop size is not a distinguishing feature between influents and effluents. A comparison of median drop sizes and dispersed oil content does not indicate that median drop size is a distinguishing feature between high-oil and low-oil content brines within the range of 1 to 204 mg/l of dispersed oil as shown in the table.

Six of nine flotation effluents had 99 percent or more of the drops with diameters of 20 μm or less. Ninety-eight percent of drops 20 μm or less was the lowest percentage for any platform. For comparison, five of eight flotation influents had 99 percent or more of the drops 20 μm or smaller. The lowest percentage was 97 for three influents. There is a general pattern of higher percentages of 20 μm and smaller drop in effluents than in influents. However, the percentage was higher for the influent than for the effluent of two platforms.

Additional comments and conclusions are referenced in Tables 199, 200, and 201. Comments are also included on the following data printouts prepared for each particle-size test run:

Drop size/Drop number histograms.
Drop size/Oil concentration histograms.
Drop size/Drop number cumulative plot on probability scale chart.
Drop size/Oil concentration cumulative plot on probability scale chart.

These data plots are not included in this report but will be presented in a more comprehensive final report on the oil-drop-size counter.

TABLE 203. DROP SIZE OIL CONCENTRATION DISTRIBUTION SUMMARY

Platform and sample point	Diameter of median drop	Proportion of drops[(1)] with diameters equal or less than		Proportion of oil[(1)] in drops equal or less than		Dispersed oil[(2)] in drops equal or less than		Total dispersed oil
		10 μm	20 μm	10 μm	20 μm	10 μm	20 μm	
	μm	%	%	%	%	mg/l	mg/l	mg/l
Flotation Influent								
WD45C	2	99	99	76	92	-	-	-
ST177	3	98	99	38	60	-	-	-
BM2C	6	89	97	28	46	12	19	42
ST131	5.5	92	99	43	76	87	179	204
BDCCF5(3)	-	-	-	-	-	-	-	-
SS107	7.5	89	97	26	43	26	43	99
SS198G	4.5	97	99	71	93	36	47	51
EI18CF	5	86	97	11	31	21	59	189
SM130B	4	94	99	7	12	6	11	88
Flotation Effluent								
WD45C	1.5	98	99	12	27	-	-	-
ST177	1.5	99	99	55	70	-	-	-
BM2C	6	91	100	67	100	6	9	9
ST131	6	85	100	48	100	2	5	5
BDCCF5	2.5	99	99	38	46	11	13	28
SS107	7	94	100	80	100	1	1	1
SS198G	4	95	99	31	47	1	1	3
EI18CF	5	86	98	28	71	22	55	78
SM130B	2.5	99	99	25	26	4	4	15

Note: All percents between 99 and 100 have been rounded to 99.

(1) From drop-size distribution tests.
(2) Calculated by multiplying percent distribution from drop-size tests by total analytically determined dispersed oil.
(3) Samples lost.

Following are specific conclusions and comments:

1. Oil-drop size distributions were obtained from photomicrographs for both flotation influents and effluents. These generally followed a log-normal distribution for any one fluid sample.

2. Dispersed oil concentrations were calculated from these distributions using the number and diameter of drops. These calculations are strongly influenced by a statistically small number of large drops.

3. The calculated dispersed oil concentrations generally compared poorly with the measured concentration obtained from the IR-Oil w/Silica Gel technique. Most often, the calculated concentration was too high, but values which were too low were also obtained.

4. The poor comparison between calculated and measured oil content can be attributed in part to statistical uncertainty in the small number of large drops. The remaining conclusions concerning drop-size must be tempered because of this poor agreement.

5. Finely dispersed oil with drop sizes from 2 to 10 μm were observed in both the influent and effluent of all the platforms studied. The percent-by-number of these drops was high, between 85 to 99 percent. The calculated weight/volume percentage concentrations of such drops were quire variable, between 7 and 80 percent. The amount of oil in drops, 10 μm or less, in flotation effluents is not significantly different from that in flotation influents. Part of this variability may be due to uncertainties in the exact number of large oil drops. The data, as analyzed, are not sufficient to identify the variations caused by shearing droplets or by upstream processing.

6. Only a statistically small number of oil drops over 20 to 40 μm were observed in gravity separator effluents (flotation influents). With the exception of Platform SM130B, the gravity separator effluents contained only a statistically small number of drops over 60 μm. The above conclusion is consistent with various manufacturers' design criteria for gravity separators including gun barrels, skim tanks and CPI units. These are often designed to remove drops in the range of 40 to 100 μm.

7. Dispersed oil droplets with sizes ranging from 20 to 60 μm were present in small numbers in all the flotation influents studied. The percent-by-number of such drops varied from 0.03 to 2.8 percent. The calculated weight/volume percent of such drops varied from 7 to 54 percent of the dispersed oil content. While such calculations are subject to considerable error, oil droplets in the size range of 20 to 60 μm usually contribute a significant amount of the dispersed oil content in flotation influents.

8. A tentative observation is that gas flotation appears to remove most oil droplets in the size range of 20 to 60 μm, which are not

removed by gravity separation. Gas flotation may be less effective in removing drops in the size range of 2 to 10 μm, but this has not been proven. Drop size data which is more consistent with measured oil contents would be needed to verify this latter result.

9. Flotation units are generally effective in removing dispersed oil from brine. The total dispersed oil content of four of seven platforms was less than 10 mg/l.

10. The two platforms, EI28CF and SM130B, that did not employ a flotation chemical were highest and third highest in flotation effluent dispersed oil.

11. The platform, BDCCF5, that had the second highest flotation effluent dispersed oil content had the highest flotation unit hydraulic loading of platforms for which oil content tests were run with particle-size tests.

SECTION 17

DISCUSSION OF RESULTS

GENERAL

An important objective of the program was to identify factors affecting brine effluent oil content. Platforms were selected representing a wide spectrum of water treating equipment, producing characteristics, and physical properties of produced fluids so that these factors could be studied. The single factor considered most important was brine treatability. The operator's preliminary estimates of treatability were generally confirmed by the soluble oil and susceptibility to separation test data collected during the survey.

Each platform surveyed has been described in a separate preceding section and the test results for each have been presented. The purpose of this section is to make comparisons between platforms.

In the individual sections, all test data were reported, and sample-to-sample variations were discussed. In this section, comparisons between platforms are presented primarily in terms of averages. The effluent oil contents, the performance of gravity separators and flotation units, and the effect of system and operational factors on effluent oil content are compared.

The approach to presenting the comparisons is first to present listings describing the properties of produced fluids, the production systems, and the water treating units and then to examine the more important parameters in more detail. The descriptive information has been presented in individual platform sections and is again listed here for ease of comparison.

PRODUCED FLUIDS

There were significant differences in the ratios and the properties of the brine and crude oil of the ten platforms. A summary listing of properties is presented in Table 204.

The range for water cuts was from 10 percent to 91 percent. The brine total dissolved solids range was from 80,500 to 203,000 mg/l. The crude oil API gravity range was from 25.8 to 41.9. Significant differences can be noted for most of the properties listed in Table 204.

The parameters considered most important with respect to brine effluent oil content are discussed in following subsections.

TABLE 204. PROPERTIES OF PRODUCED FLUIDS

	Platform									
	SP65B	WD45C	ST177	BM2C	ST131	BDCCF5	SS107	SS198G	EI18CF	SM130B
Water Cut, Percent	35	64	47	27	32	91	87	10	90	19
Brine Properties										
pH	6.9	7.0	6.3	6.6	6.3	6.7	6.6	7.1	6.3	6.2
Total Dissolved Solids, mg/l (Gravimetric)	105,000	80,500	203,000	114,000	138,000	108,000	112,000	114,000	162,000	163,000
Temperature, °C	38.6	39.7	36.1	45.0	22.6	40.9	48.2	31.1	38.2	40.1
Specific Gravity(1)	1.086	1.073	1.151	1.093	1.129	1.095	1.095	1.106	1.140	1.133
Surface Tension,(1) dynes/cm	67	60	67	60	61	61	63	66	57	68
Crude Oil Properties										
API Gravity @ 15.6°C	29.5	25.8	36.8	34.2	36.7	31.4	35.2	34.0	41.9	29.2
Temperature, °C	36.0	36.9	32.9	39.1	20.0	31.8	44.5	30.2	35.1	35.0
Specific Gravity(1)	0.865	0.890	0.842	0.831	0.842	0.863	0.825	0.848	0.810	0.865
Surface Tension,(1) dynes/cm	30	30	30	25	25	28	26	27	26	26
Viscosity @ 37.8°C, Centipoise	8.24	20.21	3.47	3.41	2.85	8.26	3.71	5.24	2.44	6.92
Boiling Range, °C										
Initial Boiling Point	150	150	150	150	150	150	150	150	150	150
Final Boiling Point	480	485	480	410	480	480	500	500	480	400
	Percent recovered									
Below - 200	49.1	29.7	42.8	61.1	61.7	45.9	38.2	48.4	37.1	77.4
200 - 250	10.4	12.4	10.5	22.6	22.6	24.5	24.3	27.2	23.4	14.0
250 - 300	14.6	21.9	19.3	13.2	8.8	22.5	25.5	17.5	27.3	7.0
300 - 350	14.5	21.2	13.0	2.4	1.6	5.6	6.3	3.2	7.5	1.4
350 - 400	5.1	6.2	6.6	0.6	0.3	1.3	3.0	1.6	2.1	0.2
400 - 450	5.4	6.8	6.9	0.1	0.1	0.2	2.0	1.2	0.3	0.0
450 - 500	0.8	1.4	0.8	0.0	0.0	0.0	0.7	0.6	0.0	0.0
500 - 550	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: Brine properties are based on tests on flotation unit effluents. Crude oil properties are based on tests on crude oil samples taken after all treatment steps on the platform

(1) Specific gravity and surface tension test results are reported for approximately the listed temperature.

PRODUCTION PROCESS SYSTEMS

There were significant differences in the production systems of the ten platforms. No two were exactly alike.

Limited comparative descriptions of the platforms are presented in Table 205 with respect to percent of gas lift, gas/oil/water separators, gravity separators and flotation units. The range for percent of gas lift was from 0 to 99.8 percent. There were some common elements, but also some differences, in the gravity separation systems of all platforms. Five different flotation unit design variations were included in the survey. No two chemical addition programs were the same.

Descriptions of water treating gravity separators and flotation units are presented in the next following subsection.

WATER TREATING UNITS

The gravity separators and flotation units were described for each platform in preceding sections. A summary comparison of these units is presented in Table 206.

Three platforms had CPI gravity separators. Three had skim tanks. Two had gun barrels, and two did not have a gravity separator specifically for the purpose of treating brine prior to flotation. Sketches of the various types of gravity separators were presented in the individual platform sections. There was a wide range of hydraulic loadings. The range of loadings for tank-type separators was from 8.2 to 84 $(m^3/d)/m^2$. For CPI separators the range was from 10.2 to 580 (m^3/d)/plate pack.

One platform had a dissolved gas flotation unit. Five had four-cell mechanically-dispersed gas units. One had a four-cell hydraulically-dispersed gas unit. One had a three-cell hydraulically-dispersed gas unit, and two had one-cell hydraulically-dispersed gas units. The mean hydraulic loadings varied from less than 2 to 70 percent of the manufacturer's recommended loading.

EFFLUENT OIL CONTENT

There were significant differences in the flotation effluent mean IR-Oil, GR-Oil, dispersed oil and soluble oil contents of the ten platforms. The test data are listed in Table 207 in the order of increasing IR-Oil content.

The effluent oil content means varied from 7.6 to 77 mg/l by the GR-oil method and from 15 to 106 mg/l by the IR-Oil method. There were also significant differences in the oil content standard deviations for the different platforms. The mean IR-Oil was higher than the mean GR-Oil for all platforms except SM130B for which the means were the same.

The effluent mean soluble oil range was from 10 to 61 mg/l. Since gas flotation will remove little if any soluble oil, the soluble oil content may represent a lower limit of treatability. The data confirm that there are

TABLE 205. PRODUCTION PROCESS SYSTEMS

	Platform									
Comparison Factor	SP65B	WD45C	ST177	BM2C	ST131	BDCCF5	SS107	SS198G	EI18CF	SM130B
Portion of Water Gas Lifted, Percent	99.8	1.7	0	58	21	88	62	0	90	59
High Pressure Separators	-	-	One, 2-phase	One, 2-phase	One, 2-phase	-	One, 2-phase	One, 2-phase	Two, 2-phase	-
Medium Pressure Separators	One, 2-phase	-	-	-	-	-	-	-	-	-
Low Pressure Separators	One, 3-phase	Three, 2-phase	One, 3-phase	One, 3-phase	One, 3-phase	Four, 2-phase	Two, 2-phase	One, 2-phase	One, 3-phase	One, 3-phase
Oil Treater	One, Chem-Electric	Two, Gun Barrels	Off Platform	One, Chem-Electric	Off Platform	Two, Heater Treaters	One, Gravity	One, Chem-Electric	One, Heater Treater	Off Platform
Water Treating Gravity Separators	One, Skim Tank	None	One, Gun Barrel	One, 2-pack CPI	One, Gun Barrel	Two, Skim Tanks	None	One, 1-pack CPI	One, Skim Tank	Two, 2-pack CPI's
Flotation Unit	Wemco, Mechanical	Monosep, Hydraulic	Wemco, Hydraulic	Wemco, Mechanical	Wemco, Mechanical	Monosep, Hydraulic	Wemco, Mechanical	Tridair, Hydraulic	PCE, Dissolved	Wemco, Mechanical
Down-Hole Chemical Addition										
Paraffin Inhibitor	No	Yes	No	No	No	No	No	No	No	No
Corrosion Inhibitor	No	Yes	No	No	No	No	No	No	No	No
Platform Chemical Addition										
Foam Inhibitor	No	Yes	Yes	No	No	No	No	No	No	Yes
Biocide	Continuous	Batch	Batch	No	No	Batch	No	No	No	No
Demulsifier	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Scale Inhibitor	No	No	No	No	No	Yes	Yes	Yes	No	No
Flotation Aid	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No

(1) In lift gas.

TABLE 206. WATER TREATING UNITS

	Platform									
	SP65B	WD45C	ST177	BM2C	ST131	BDCCF5	SS107	SS198G	EI18CF	SM130B
Gravity Separators										
Type Number	Skim Tank One	None	Gun Barrel One	CPI One, 2-pack	Gun Barrel One	Skim Tank Two	None	CPI One, 1-pack	Skim Tank One	CPI Two, 2-pack
Hydraulic Loading, m^3/d	955	-	919	1,160 (4)	241	945 (5)	-	10.2 (4)	7,949	970 (4)
$(m^3/d)/m^2$	21	-	31	(580) (4)	8.2	27 (5)	-	(10.2) (4)	84	(242) (4)
Inlet Distribution (1)	Good	-	Fair	-	Fair	Poor	-	-	Fair	-
Short Circuiting Potential (1)	Low	-	High	-	High	High	-	-	Moderate	-
Flotation Unit										
Trade Name	Wemco	Monosep	Wemco	Wemco	Wemco	Monosep	Wemco	Tridair	PCE	Wemco
Number of Cells	4	1	4	4	4	1	4	3	1	4
Method of Gas Dispersion	Mechanical	Hydraulic	Hydraulic	Mechanical	Mechanical	Hydraulic	Mechanical	Hydraulic	Dissolved	Mechanical
Design Capacity, m^3/d	6,135	981	2,460	4,090	1,638	3,180	2,460	795	10,900	6,135
Average Loading, (2) m^3/d	655	691	849	995	111	1,890	733	9.2	2,920	690
Average Loading, Percent of Design	11	70	35	24	7	59	30	1.2	27	11
Overflow Rate Per Cell, $(m^3/d)/m^2$	202	135	300	255	60	177	260	8.1	59	207
Froth Flow, Percent of Average Loading	46	10	8	17	117	<1	19	11	0.5	41
Recycle Flow, Percent of Average Loading	None	570	510	None	None	670	None	39,000	None	None

(1) Subjective opinion based on review of separator configuration.
(2) Based on effluent flow
(3) Based on total surface area of all separation cells.
(4) Cubic meters per day per plate pack.
(5) For each of two skim tanks.

TABLE 207. PLATFORM FLOTATION EFFLUENT OIL CONTENT COMPARISON

Platform	GR-Oil, mg/l		IR-Oil, mg/l		Dispersed oil, mg/l		Soluble oil, mg/l		Soluble oil, Fraction of IR-Oil
	$\bar{x}$	(s)	$\bar{x}$	(s)	$\bar{x}$	(s)	$\bar{x}$	(s)	%
SS107	7.6	(5.2)	15	(3.7)	1.6	(1.5)	13	(2.7)	87
SS198G	18	(9.2)	36	(7.8)	5.7	(7.7)	31	(2.7)	86
BDCCF5	26	(6.9)	36	(8.3)	26	(8.6)	10	(2.3)	28
ST131	12	(13)	37	(19)	5.9	(13)	28	(3.1)	76
BM2C	22	(6.7)	39	(4.2)	4.9	(5.1)	36	(4.1)	92
SM130B	48	(16)	48	(16)	23	(13)	25	(4.7)	52
EI18CF	52	(24)	76	(38)	63	(30)	13	(13)	17
WD45C	63	(95)	81	(109)	66	(106)	30	(32)	37
ST177	64	(74)	95	(103)	92	(126)	21	(13)	22
SP65B	77	(73)	106	(99)	38	(80)	61	(15)	58

Note: Some numbers do not check because of rounding. Two significant figures have been retained in all numbers below 100.

$\bar{x}$ = Mean
(s) = Standard Deviation

significant differences in treatability of brines from different platforms.

Table 208 presents an empirical rating of brine treatability as judged by mean soluble oil content.

The last column in Table 207 illustrates that most of the oil in some brines was soluble and in other brines was dispersed. Dispersed oil in relation to treating unit performance is discussed in the next following subsections. Additional discussion of soluble oil in relation to water cut is presented in a following subsection.

There were significant negative correlations between effluent IR-Oil content and surface tension sample-to-sample for each platform. A summary listing of mean surface tension and linear regression slope and correlation coefficient is presented in Table 209 for all platforms.

FLOTATION UNIT PERFORMANCE

There are significant differences in the amount of dispersed oil remaining in the ten flotation effluents. The platforms are listed in the order of increasing mean dispersed oil in Table 210. The range for the means was from 1.6 to 92 mg/l. Units reducing dispersed oil to the lowest levels can be considered most effecitve.

Four factors of potential significance to flotation unit performance are listed in Table 210. These are influent oil concentration, hydraulic loading, flotation chemical addition rate, and the type of flotation unit. There are

TABLE 208. SOLUBLE OIL TREATABILITY RATING

Platform	Treatability	Effluent mean soluble oil content, mg/l
BDCCF5	Easy	10
SS107	Easy	13
EI18CF	Easy	13
Mean		12
ST177	Medium	21
SM130B	Medium	25
ST131	Medium	28
WD45C	Medium	30
SS198G	Medium	31
Mean		27
BM2C	Difficult	36
SP65B	Difficult	61
Mean		48

TABLE 209. SURFACE TENSION SUMMARY

Platform	Mean surface tension	Linear regression	
		Slope	Correlation coefficient
SP65B	67	-6.9	-0.96
WD45C	60	-17.8	-0.87
ST177	67	-11.6	-0.70
BM2C	60	-0.4	-0.5
ST131	61	-1.24	-0.65
BDCCF5	61	-2.94	-0.73
SS107	63	-6.1	-0.92
SS198G	66	-4.5	-0.68
EI18CF	57	-3.2	-0.84
SM130B	68	-3.0	-0.32

significant design and operation differences for all platforms. A single predominant factor that determines flotation effectiveness in removing dispersed oil has not been identified by simple bivariate data analysis. Therefore, special features of each platform are discussed separately.

TABLE 210. PLATFORM FLOTATION UNIT PERFORMANCE COMPARISON

Platform	Flotation effluent dispersed oil		Flotation influent total IR-oil		Hydraulic loading	Flotation chemical addition rate	Flotation unit description
	x mg/l	(s) mg/l	x mg/l	(s) mg/l	% of design	ppmv	
SS107	1.6	(1.5)	215	(49)	24-31	14	4 - cell (M)
BM2C	4.9	(5.1)	158	(65)	18-39	17	4 - cell (M)
SS198G	5.7	(7.7)	130	(39)	<1-2.5	255	3 - cell (H)
ST131	5.9	(13)	386	(199)	3-12	126	4 - cell (M)
SM130B	23	(13)	156	(105)	1-20	0	4 - cell (M)
BDCCF5	26	(8.6)	113	(15)	50(1)	5	1 - cell (H)
SP65B	38	(80)	170	(147)	11(1)	17	4 - cell (M)
EI18CF	63	(30)	222	(210)	24-30	0	1 - cell (D)
WD45C	66	(106)	1169	(3409)	68-75	7	1 - cell (H)
ST177	92	(126)	432	(394)	26-47	26	4 - cell (H)

Note: (M) = Mechanical gas dispersion
(H) = Hydraulic gas dispersion
(D) = Dissolved gas

(1) Estimated mean.

Platform SS107 had the lowest mean dispersed oil content of 1.6 mg/l. The influent oil loading was moderate and uniform, and the hydraulic loading uniform and not over 31 percent of design. Chemical addition was intermediate with respect to other platforms at 14 ppmv. The flotation unit was a four-cell unit with mechanical gas dispersion. There was a general pattern of consistency, but none of the listed factors explains why the oil content was lowest. Platform SS107 was one of only two that did not have a water-treating gravity separator.

Platform BM2C had the second lowest mean dispersed oil content at 4.9 mg/l. BM2C was very similar to SS107 with respect to the type of flotation unit and the consistency of the listed operational parameters.

Mean dispersed oil was reduced to 5.7 mg/l on SS198G in a three-cell hydraulically-dispersed gas flotation unit. However, the mean hydraulic loading was less than 2 percent and the chemical addition rate averaged 255 ppmv. These parameters are non-typical and limit the comparability of the performance of this unit to the others.

The four-cell mechanical dispersed gas unit on ST131 reduced the mean dispersed oil content to 5.9 mg/l. The influent oil was third highest of the ten. However, the maximum hydraulic loading was only 12 percent and the chemical addition rate was 126 ppmv which is high compared to that of most other platforms.

On SM130B, mean dispersed oil was reduced to 23 mg/l in a four-cell mechanical unit. Influent oil loading was moderate and the maximum hydraulic loading only 20 percent. Flotation chemical was not added.

On BDCCF5, mean dispersed oil was reduced to 26 mg/l in a one-cell unit with hydraulic gas dispersion. The influent oil loading was the lowest and most consistent of any platform. The hydraulic loading was second highest at 59 percent and chemical addition relatively low at 5 ppmv.

On Platform SP65B, mean dispersed oil was reduced to 38 mg/l in a four-cell mechanical unit. Influent oil content was moderate, hydraulic loading only 11 percent, and the chemical addition rate was 17 mg/l. Reference to Section 6 shows that two high oil content values occurred corresponding to high influent values, when chemical feed was off. If the two high effluent values are excluded, the mean effluent dispersed oil is 14 mg/l.

On EI18CF, mean dispersed oil was reduced to 63 mg/l in the only dissolved gas flotation unit included in the survey. Flotation chemical was not added. Some influent oil contents were high, over 500 mg/l. The high influent values were associated with high effluent values. These factors may account for a comparatively high dispersed oil content.

On Platform WD45C, mean dispersed oil was reduced to 66 mg/l in a one-cell unit with hydraulic gas dispersion. This unit had the highest hydraulic loading in the survey with a maximum of 75 percent of design. There was not a separate water-treating gravity separator in the system. Excursions in effluent oil content occurred, usually associated with high influent values.

On Platform ST177, mean dispersed oil in the effluent was 92 mg/l. For six days of the survey, this platform was in a general upset condition as operations were recovering from the effects of a hurricane. For this reason, the test results from this platform cannot reasonably be compared to the others.

In summary, because of the many differences between platforms, it is not possible to make quantitative conclusions on the factors most important to flotation unit performance. Therefore, considering the information in this section and in the individual platform sections, general conclusions are presented concerning flotation unit performance.

High influent oil content excursions over 500 mg/l usually, but not always, had a marked effect on effluent oil content (see influent and effluent oil content data plotted in Figures 8, 9, 21, 22, 33, and 34). An influent oil content below 300 mg/l appears desirable. Some lightly loaded units may handle more than this.

Oil content usually increased when chemical feed was interrupted. Chemical addition is employed to enhance oil separation. The selection of flotation chemicals and addition rate were not part of this study.

Hydraulic loading was not evaluated comprehensively during the study because most units operated at relatively low and uniform loadings, and problems were experienced in flow monitoring. Also, simple statistical analysis did not demonstrate a substantial general correlation between flotation influent oil content and effluent oil content, except when influent excursions occurred. Intuitively, hydraulic loading and oil/loading are important parameters which could be studied by more complex data analysis and/or additional testing.

GRAVITY SEPARATOR PERFORMANCE

There were significant differences in oil content of gravity separator effluents. See Table 211. There were significant differences in the oil separation rates of gravity separator influents and effluents from different platforms as measured by the susceptibility to separation test. There was a general relationship between separation rate measurements and gravity separator effluent oil content. For some platforms, other factors were more important in separator performance than separation rate as measured by the tests.

Three platforms had CPI separators, three had skim tanks, two had gun barrels and two had no gravity separator specifically for water treating. The different types of separators were described in the individual platform sections.

The principal purposes of the gravity separators in the water handling systems are (1) to remove a large percentage of the oil from the water upstream of the flotation units, and (2) to protect the flotation units from the effects of slugs of oil which might enter the water handling systems as a result of upsets in the production processing systems. Where appropriate

TABLE 211. PLATFORM GRAVITY SEPARATOR PERFORMANCE COMPARISON

Platform	Water treatment separator type	Effluent IR-oil, mg/l		Settling tests			Hydraulic loading		Brine/oil Δ specific gravity	Brine temperature
				Settling time		Sample(1) point	Tank	CPI		
				5 min	120 min					
		x̄	(s)	mg/l	mg/l	-	$(m^3/d)/m^2$	(m^3/d)/plate pack	-	°C
BDCCF5	Skim Tank	113	(15)	103	53	9--1	27	-	.232	41.1
SS198G	CPI	130	(39)	209	117	8--1	-	10	.258	36.5
SM130B	CPI	156	(105)	169	107	8K-1	-	242	.268	40.9
BM2C	CPI	158	(65)	219	128	8--1	-	580	.262	45.6
SP65B	Skim Tank	170	(147)	311	123	5A30	21	-	.221	33.0
SS107	None(2)	215	(49)	119	86	9--1	120	-	.270	49.2
EI18CF	Skim Tank	222	(210)	151	39	8--1	84	-	.330	39.9
ST131	Gun Barrel	386	(199)	851	239	8--1	8.2	-	.287	22.8
ST177	Gun Barrel	432	(394)	210	100	9--1	31	-	.309	36.6
WD45C	None(3)	1169	(3409)	59	54	9--1	38	-	.133	40.2

(1) Separator influents were sampled if a sample tap was available. Other points and effluents were sampled when influent samples could not be taken.

(2) Gravity separation was in an oil treater with the primary function of separating water from oil.

(3) Gravity separation was in two gun barrels with the primary function of separating water from oil.

sample points were available for both the influents and effluents of the gravity separators, the data in the tables of major brine tests show that all the gravity separators were successful in reducing the oil contents of the waters. An exception occurred on Days 5 and 6 on EI18CF when the IR-Oil content of the effluent from the skim tank was higher than that of the influent. This might have been caused by the skim tank's operating at too low a level so that previously separated oil was swept from the tank by the inlet flow. The oil content in the effluent decreased appreciably on Day 7 after the level of the tank had been raised (see Table 163 and Observations and Operator Reports, Section 14).

Major upsets, i.e., incidents in which the IR-Oil content of samples from the influent to the gravity separator was so high it was reported in percent instead of mg/l, occurred on ST177 and ST131. In both cases, the gravity separators prevented slugs of oil from reaching the flotation units for several days (see Tables 63 and 94 and Observations and Operator Reports, Sections 8 and 10). Both of these platforms are equipped with gun barrel type gravity separators.

Less severe upsets occurred on SP65B and SM130B. The maximum IR-Oil content for the gravity separator influent on SP65B was 96,000 mg/l; the upset condition persisted for two days. The upset condition on SM130B was of much shorter duration, i.e., only one "abnormally" high value was reported for the IR-Oil content of the gravity separator influent. This maximum value was 11,549 mg/l. Although these high values were reflected by unusually high oil contents in the flotation unit influent samples, the gravity separators on both platforms retained nearly all the oil (See Tables 17 and 181 and Effluent Oil Content, Section 6 and Observations and Operator Reports, Section 15). SP65B is equipped with a skim tank as the gravity separator, and SM130B with a CPI.

The platforms are listed in Table 211 by increasing order of the mean IR-Oil contents of the gravity separator effluents. Standard deviations for the oil contents are also given. The temperature and the difference in specific gravity of the brine and oil are given for each separator. For a general comparison of loading, the cubic meters per day per square meter are shown for the tank separators, and the cubic meters per day per plate pack for plate separators. There are appreciable variations in all listed parameters.

The means of the IR-Oil content of the gravity separators' effluents varied from 113 to 1,169 mg/l, and the standard deviations from 15 to 3,409 mg/l. The gravity separators, in increasing order of the means of the effluent oil contents, were a skim tank, the three CPI separators, a skim tank, a dual purpose oil treater, a skim tank, two gun barrels and a dual purpose gun barrel. The three CPI separators produced relatively uniform oil contents, as did the two skim tanks with hydraulic loadings below 30 $(m^3/d)/m^2$. The mean values of the IR-Oil contents of the gun barrel effluents were higher than those of the skim tanks and CPIs but, as discussed above, both platforms with gun barrels experienced major upsets of several days' duration during the surveys.

This survey has demonstrated that gravity separators will remove substantial amounts of oil from produced brines and protect the flotation units from slugs of oil which enter the water handling system as the result of upsets in the production processing systems. The superiority of one type of gravity separator over the other types was not demonstrated.

Table 211 also lists mean oil contents for 5-minute and 120-minute settling periods from the susceptibility to separation tests. These data show there are wide variations in settling rates between platforms. After 5 minutes of settling, the lowest mean oil content was 59 mg/l for WD45C; and the highest, 851 mg/l for ST131. After 120 minutes the lowest was 39 mg/l for EI18CF; and the highest, 239 mg/l for ST131. Curves representing the data from the susceptibility to separation tests are shown in Figures 120 and 121. These curves also illustrate the differences in separation rates for different oils and brines.

There is a general relationship between gravity separator effluent oil content and rate of separation of oil as indicated by settling tests. This is illustrated by the data in Table 212. For seven of eight platforms, a high proportion of separator effluent IR-Oil tests fall in the range established by 5-minute and 120-minute settling rate tests (susceptibility to separation). Thirty-one percent of the oil content tests of ST131 were in the range, even though influent oil contents were frequently in the range of percent rather than mg/l. Only 8 percent of the oil content test results of SS107 fell in the range, and none of those of WD45C. These two platforms do not have a separate water treating gravity separator and the results are presented for comparison only.

The settling tests indicated the lowest separation rate for Platform ST131. The temperature of the brine was lower for this platform than for any other.

Platform WD45C had the smallest oil/water specific gravity difference. Contrary to expectations the oil separated the easiest based on the 5-minute test. Factors other than gravity difference predominated.

BRINE SOLUBLE OIL

Four tests were used as indicators or measurements of soluble oil. They were the IR-Oil w/Silica Gel test, the IR-Scan test, the equilibration test, and the filtered brine test. The tests indicated there are variable amounts of soluble components in brines from different platforms.

The IR-Oil w/Silica Gel test results have already been presented and discussed as soluble oil. When the program plan was developed water cut was proposed as a parameter to examine for correlation with soluble oil, the theory being that brine from new wells with a low water/oil ratio would be high in soluble oil components.

Table 213 presents a listing of mean soluble oil in increasing order. The corresponding water cuts for the produced fluids are also listed. For the first eight platforms listed, the water cuts are exactly in inverse order

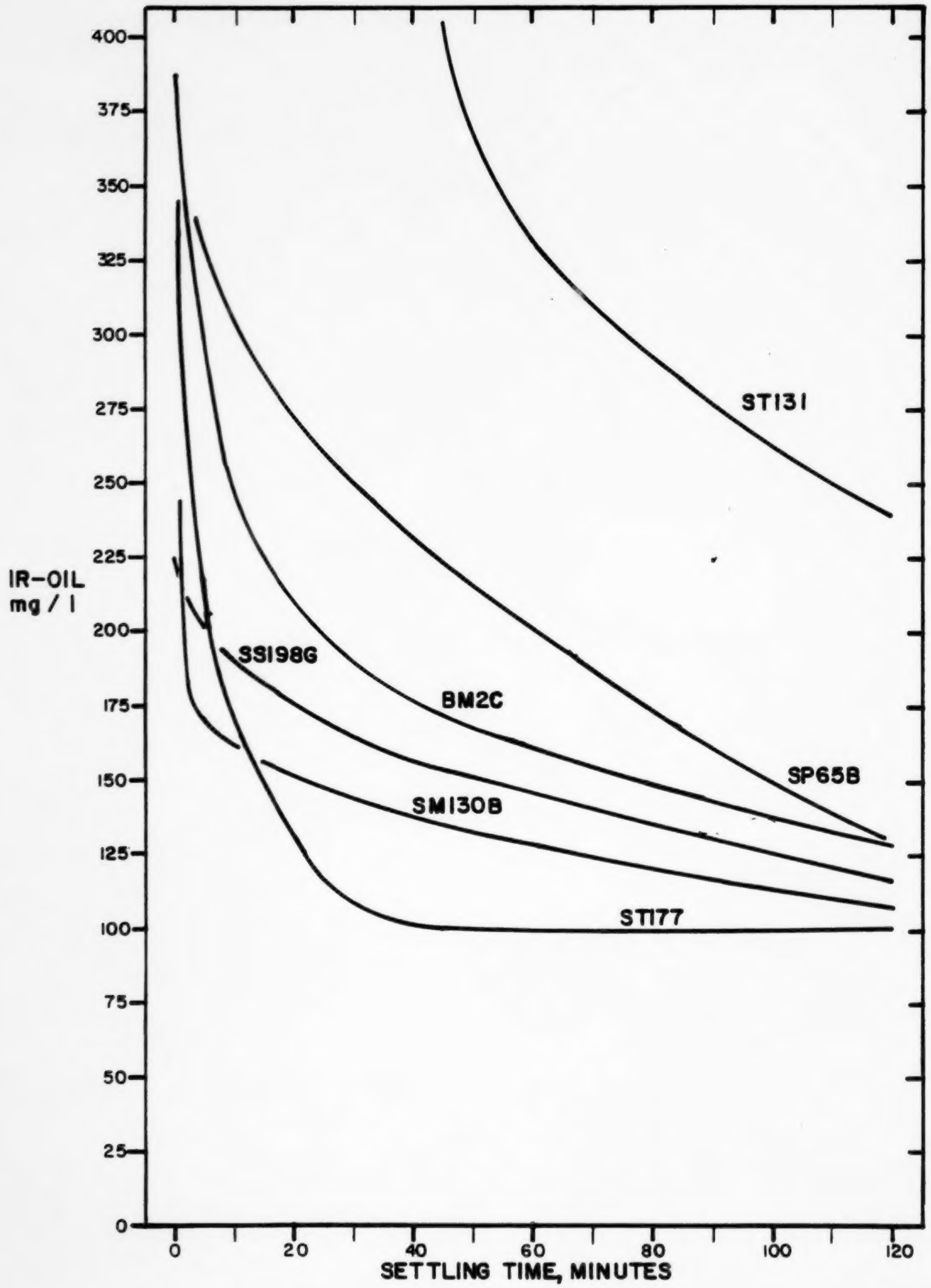


Figure 120. Susceptibility to separation.

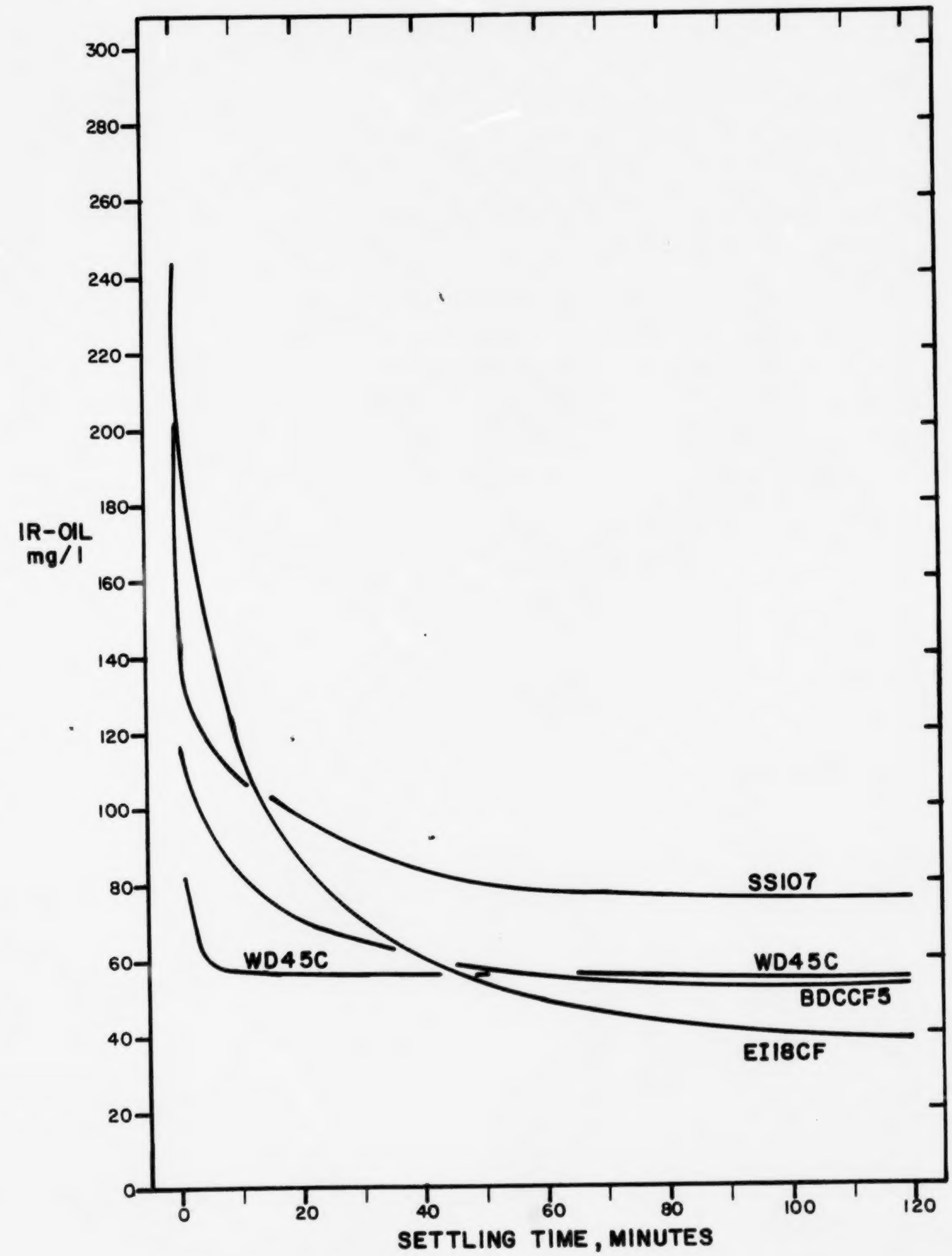


Figure 121. Susceptibility to separation.

TABLE 212. SEPARATOR EFFLUENT OIL CONTENT SETTLING TEST COMPARISON

Platform	Water treatment separator type	Gravity separator IR-Oil: Mean mg/l	Gravity separator IR-Oil: Proportion in settling(1) Test range Percent	Settling test range(1) IR-Oil content: 5 min mg/l	Settling test range(1) IR-Oil content: 120 min mg/l
BDCCF5	Skim Tank	113	85	121	43
SS198G	CPI	130	90	237	101
SM130B	CPI	156	80	192	100
BM2C	CPI	158	66	261	105
SP65B	Skim Tank	170	60	331	113
SS107	None(2)	215	8	136	56
EI18CF	Skim Tank	222	60	163	38
ST131	Gun Barrel	386	95	1,259	168
ST177	Gun Barrel	432	31	271	85
WD45C	None(3)	1,169	0	68	49

(1) The settling test range is reported as the highest 5-minute settling test result and the lowest 120-minute test result.
(2) Gravity separation was in an oil treater with the primary function of separating water from oil.
(3) Gravity separation was in two gun barrels with the primary function of separating water from oil.

TABLE 213. SOLUBLE OIL AND WATER CUT

Platform	Mean soluble oil mg/l	Water cut %
BDCCF5	10	91
EI18CF	13	90
SS107	13	87
WD45C	18(1)	64
ST177	21	47
SM130B	25	19
ST131	28	18(3)
SS198G	31	10
BM2C	36	27
SP65B	57(2)	35

(1) This mean does not include the three highest soluble oil test values which appear inconsistent.
(2) This mean does not include the two highest test values which appear inconsistent.
(3) The water cut does not include one well producing only water.

to the soluble oil. The two highest mean soluble oil values do not follow the precise order of the others. The calculated least squares linear regression equation is:

$$\text{Soluble oil, mg/l} = 40 - 0.29\ (\text{water cut, \%})$$
$$r = -0.67$$

A significant correlation is indicated of decreasing soluble oil concentration with increasing water cut.

The API gravity, as a parameter indicating lighter or heavier oil, was examined for correlation with soluble oil. Brine total dissolved solids and pH were also examined for correlation. These parameters do not show a significant relationship to soluble oil by simple bivariate analysis.

IR-Scan tests were run on brine Freon extracts only during Phase I. Carboxilic acid groups were indicated to be present in the extracts from all three platforms. The data was qualitative and did not indicate whether the acid groups were from the produced fluids or the addition chemicals.

As explained in Section 5, the filtered brine test requires additional development to establish it as a reliable indicator of soluble materials or treatability.

The equilibration test provides an indication of soluble components in brine of the same order of magnitude as the IR-Oil w/Silica Gel test.

For Phase I, two equilibration tests were run on the crude oil from each platform. Duplicate tests were run with oil/water ratios of 4/1 and a brine TDS of 100,000 mg/l. For Phase II, two tests were run for each platform but they were not duplicates. Both tests were run at the formation-brine TDS. One was run at a 4/1 oil/water ratio. The plan was to run the other test at the formation water-cut ratio. This was done for all platforms except SS198G which was unintentionally run at a different oil/water ratio.

The equilibration test results are listed in Table 214. The number of tests is too limited for definitive conclusions. Following are general comments.

The equilibration tests show that for all individual test runs some oil is partitioned into the brine. The duplicate tests during Phase I all checked reasonable well. For two Phase I platforms, the equilibration IR-Oil and the platform mean soluble oil checked reasonably well. The third platform did not match well in this respect.

Considering Phase II tests at formation oil/water ratio, the equilibrated brine soluble oil checked closely with mean soluble oil for platforms BDCCF5, SS107, and SM130B.

The equilibration test on SS198G was run at the wrong oil/water ratio. Two-hundred-fifty-five ppmv of flotation chemical was added to the brine on SS198G. Although not proven, this may have contributed to the mean soluble

TABLE 214. EQUILIBRATION TESTS

Platform	Brine TDS Produced mg/l	Brine TDS Test mg/l	Oil/water ratio Produced -	Oil/water ratio Test -	Equilibrated brine IR-oil mg/l	Equilibrated brine IR-oil w/ silica gel mg/l	Equilibrated brine Soluble oil mg/l	Platform mean soluble oil mg/l
Phase I								
SP65B	141,000	100,000 100,000	1.89/1	4/1 4/1	50 56	- -	- -	61
WD45C	121,000	100,000 100,000	0.57/1	4/1 4/1	137 125	- -	- -	30
ST177	211,000	100,000 100,000	1.15/1	4/1 4/1	31 17	- -	- -	21
Phase II								
BM2C	105,000	105,000 105,000	2.64/1	4/1 2.64/1	8 8	6 6	2 2	36
ST131	131,000	131,000 131,000	4.4/1(2)	4/1 4.4/1	35 35	23 23	12 12	28
BDCCF5	112,000	112,000 112,000	0.10/1	4/1 0.1/1	90 15	10 3	80 12	10
SS107	106,000	106,000 106,000	0.15/1	4/1 0.15/1	12 14	8 2	4 12	13
SS198G	116,000	116,000 116,000	8.6/1(3)	4/1 0.15/1	12 9	6 4	6 5	31
EI18CF	164,000	164,000 164,000	0.11/1	4/1 0.11/1	11 9	6 5	5 4	13
SM130B	163,000	163,000 163,000	4.3/1	4/1 4.4/1	92 26	6 2	36 24	25

(1) Summation method.
(2) Not including one well that produced only water.
(3) Based on metered oil and water flow, Days 5-9.

oil which is higher than that of the equilibrated brine.

SUSPENDED SOLIDS TESTS

As discussed in the individual platform sections, significant correlations between suspended solids and brine oil content were not identified. Also as discussed in Section 18, the precision and accuracy of the field survey tests were questionable. For these reasons, indepth between-platform comparisons of suspended solids in relation to oil content are not presented. A cursory review of the data did not indicate a significant relationship.

SULFATE REDUCING BACTERIA

The sulfate reducing bacteria counts in brine effluents were 100 per milliliter or less for all platforms except ST131. Counts up to 1,000,000 per milliliter were obtained on some tank bottom samples and sump effluent samples.

None of the survey platforms was observed to have a black-water problem as may be caused by iron sulfide and other sulfide compounds. For this particular survey, sulfate reducing bacteria did not appear to relate to effluent oil content.

SECTION 18

SPECIAL TEST EVALUATIONS

GENERAL

Test method development was not included in the Program when it was initiated. The Program was to be carried out using established test methods. As the survey proceeded, it became apparent that the suspended solids test and the filtered brine test were deficient and some test evaluation studies were needed. In addition, some special tests were run to determine the effect of acidification on the IR-Oil test.

SUSPENDED SOLIDS TESTS

The suspended solids test procedure used closely followed ASTM and EPA procedures, which are essentially the same. A full description of the procedure is presented in Appendix A.

A brief review of the steps in the procedure follows. Brine was drawn through a tared millipore filter directly from the sample taps on the platforms; the filter was washed with 50 ml of deionized (D.I.) water, the filter was returned to the laboratory, dried and weighed to obtain Freon solids; the filter was washed with Freon, dried and weighed to obtain Freon soluble solids; the filter was washed with HCl, dried and weighed to obtain acid soluble solids. Blanks consisted of clean filters exposed to prefiltered brine and the various wash steps. Numerical blank adjustments were developed for the water wash step, the Freon wash step, and the acid wash step.

Nature of Problem

A significant number of suspended solids test results were negative which is not reasonable. Several clean filters were exposed to artificial brine (100,000 mg/l TDS). These synthetic brine blanks were highly variable and indicated variable amounts of salt were being retained by the filters. These blank determinations are reported in Table 215. The substantial range in these blanks implies poor precision since a comparable range would be expected in the samples.

The blanks actually used for the tests were determined on prefiltered brine from each platform according to the ASTM procedure. These blanks are reported for information only in Table 216.

TYPING GUIDE SHEET

TABLE 215. SUSPENDED SOLIDS BLANKS ON ARTIFICIAL BRINE[1]

Filter number	Tare weight of filter, grams	Net gain(+) or loss(-) of filter weight, grams: After brine and DI water wash, B	After Freon wash, B_o	After acid wash, B_a
1	.1229	+.0169	+.0009	-.0067
2	.1231	+.0111	+.0011	-.0047
3	.1219	+.0058	+.0002	-.0017
4	.1217	+.0100	+.0005	-.0039
5	.1222	+.0080	+.0006	-.0047
6	.1214	+.0113	0	-.0048
7	.1223	+.0136	+.0007	-.0065
8	.1234	+.0114	0	-.0042
9	.1238	+.0125	+.0008	-.0050
10	.1225	+.0177	+.0004	-.0096
11	.1219	+.0110	+.0007	-.0037
12	.1224	+.0096	+.0004	-.0022
13	.1128	+.0163	+.0005	-.0065
14	.1122	+.0090	+.0008	-.0027
15	.1130	+.0084	+.0006	-.0031
16	.1134	+.0081	+.0004	-.0025
17	.1119	+.0085	+.0003	-.0034
18	.1124	+.0118	0	-.0039
19	.1113	+.0055	+.0002	-.0008
20	.1121	+.0068	+.0006	-.0011
Average net change		+.0107	+.0005	-.0041
Equivalent concentration,[2] mg/l				
Average		+ 10.7	0.5	- 4.1
Minimum		+ 5.5	0.0	- 1.1
Maximum		+ 17.7	1.1	- 9.6
Standard Deviation		3.5	0.3	2.1

(1) Brine strength = 100,000 TDS.
(2) For one liter samples.

TABLE 216. SUSPENDED SOLIDS BLANKS RUN ON PLATFORM SPECIFIC BRINE

Platform	Tare weight, of filter, grams	Vol. of brine, ml	Net gain(+) or loss(-) of filter weight, grams		
			After brine and DI wash, B	After Freon, wash, B_o	After acid wash, B_a
SS107	.1341	250	+.0080	-.0001	-.0010
BM2C	.1329	250	+.0083	0	-.0016
ST131	.1326	250	+.0051	-.0001	+.0002
SM130B	.1338	250	+.0083	+.0001	-.0008
SS198G	.1329	250	+.0075	+.0001	-.0015
BDCCF5	.1369	250	+.0046	0	+.0001
EI18CF	.1319	250	+.0343	+.0001	-.0126
EI18CF	.1314	100	+.0318	-.0006	-.0150
EI18CF	.1294	50	+.0321	+.0003	-.0143

Filter Wash Blank Experiments

Because washing with 50 ml of deionized water did not provide stable blanks, it was assumed that the same washing procedure was not adequate for test samples. Any retained salt would be reported as suspended solids. If the salt were then removed by the acid wash step, it would be reported as acid soluble solids. Experiments were conducted to determine an adequate water-wash volume.

The procedure for the water-wash experiment was as follows: A 50 ml sample of brine from each platform was filtered according to the TSS procedure and the filter dried and weighed. This filter became the "unfiltered" sample for that platform. The same brine was then filtered again and the filter dried and weighed. This filter became the "prefiltered" sample for that platform.

Each filter was then washed with 50 ml of deionized water according to the TSS method, dried and weighed. This process was repeated five times and the dry weight recorded after each wash. After five washes, the experiment was stopped. The filter weights seemed to be leveling near the tare weight. More important, however, the filters were becoming ragged around the edges and would undoubtedly continue to lose weight after each handling as glass fiber material was lost.

The experimental washing results are presented in Table 217, and in Figure 122. It is apparent that the first 50-ml wash leaves substantial salt on the filter and the weight of the filter tends to stabilize after five 50-ml washes.

It was very interesting to notice that in every case the weight gain was greater in the prefiltered sample than in the unfiltered sample. This experiment was done with a millipore filter holder which supports the fiber filter with a fine glass frit. It is very unlikely, therefore, that any filter material became suspended in the brine after the first filtering. Also, a sample of brine was aerated prior to filtering and the same phenomenon was exhibited. At this point it was determined that to pursue this problem further would become very expensive and should not be done as part of this program.

It was demonstrated that a 250-300 ml wash volume would be much more effective in removing the water soluble salts. It also appears that some of the variability in this method is the result of damage to the filters and subsequent loss of filter material. After the filters have been in and out of the filter holder several times the edges are noticeably worn even when the greatest care is taken in handling them. If a more durable filter material were used and/or a better holder developed, the method would be more reliable.

FILTERED BRINE TEST

Nature of the Problem

When the IR-Oil content of filtered brine was compared to unfiltered brine, the oil content of the filtered brine was consistently higher for some platforms. Analysis indicated that the filtered brine IR-Oil of effluents exceeded the regular IR-Oil when the dispersed oil was less than 15 mg/l. Platforms SS107, BM2C, ST131, and SS198G provide examples of this. The mean filtered brine IR-Oil was 30 mg/l higher for SS198G. The filtered brine IR-Oil results of effluents were less than the regular IR-Oil results when the dispersed oil exceeded about 15 mg/l. Platforms WD45C, BDCCF5, EI18CF, SM130B, SP65B, and ST177 are examples of this.

The filtered brine IR-Oil was consistently less than the regular IR-Oil for gravity separator influents and effluents.

Saved Filter Experiments

When the standard IR-Oil tests were run, significant staining was observed of the filters used to clarify the Freon before the absorbance measurement. The survey team was requested to determine how much oil was being retained on the filters when the standard IR-Oil tests were run to explain lower IR-Oil results.

The filters from IR-Oil tests run on four of the platforms were retained. The amount of oil on the filters was determined later by Freon extraction in the laboratory and IR-absorbance. Most of the retained filters were from

TABLE 217. SUSPENDED SOLIDS BLANK WASHING STUDIES

Platform	Filter tare weight, gms	Net gain in filter weight relative to tare weight, gms				
		After 1st wash	After 2nd wash	After 3rd wash	After 4th wash	After 5th wash
Initial Brine Not Prefiltered						
SS107	.1345	.0118	.0065	.0052	.0044	.0050
BM2C	.1336	.0036	.0025	.0014	.0015	.0013
ST131	.1366	.0192	.0122	.0088	.0080	.0069
SS198G	.1315	.0130	.0090	.0067	.0049	.0045
EI18CF	.1309	.0238	.0159	.0130	.0117	.0110
BDCCF5	.1305	.0137	.0086	.0063	.0055	.0051
SM130B	.1360	.0219	.0117	.0093	(1)	(1)
Initial Brine Prefiltered						
SS107	.1322	.0240	.0132	.0087	.0050	.0039
BM2C	.1363	.0501	.0306	.0059	.0046	.0041
ST131	.1317	.0284	.0200	.0131	.0096	.0096
SS198G	.1336	.0254	.0142	.0092	.0061	.0046
EI18CF	.1320	.0347	.0240	.0150	.0088	.0066
BDCCF5	.1323	.0211	.0122	-.0020	-.0020	-.0023
SM130B	.1364	.0379	.0211	.0117	.0072	.0062

Note: Fifty milliliters of deionized water was used for each wash.

(1) Filtered damaged.

IR-Oil tests but a few were from GR-Oil tests. All test results were reported in milligrams per liter of the original brine sample for comparability.

The filters were retained in two ways. Some were placed in a bottle with 100 ml of Freon immediately after completion of the field test. Others were placed in bottles that did not contain Freon. These filters were air dried in the laboratory before extraction with Freon. Blanks were run on unused filters.

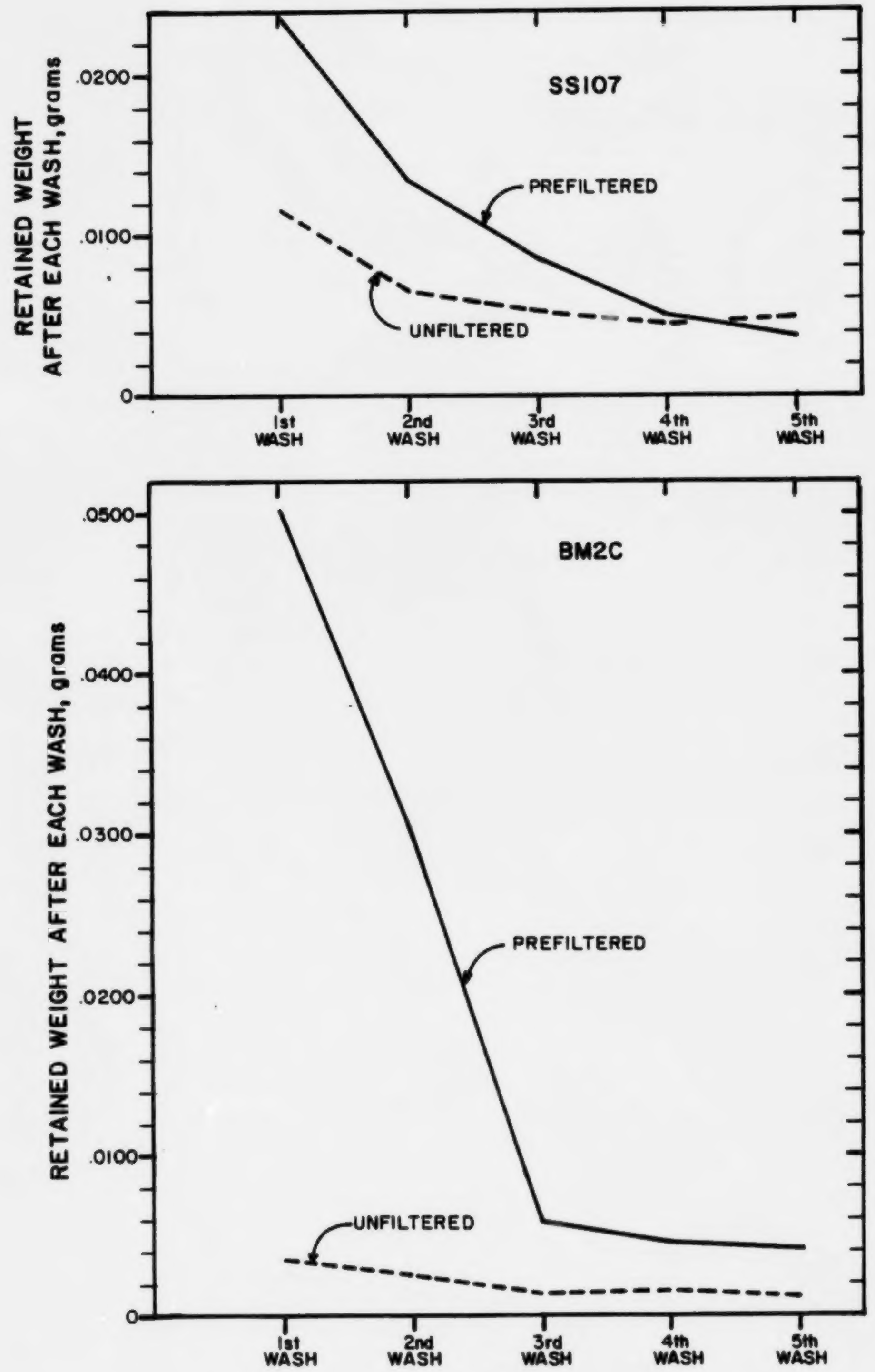


Figure 122. Suspended solids water wash blank studies.

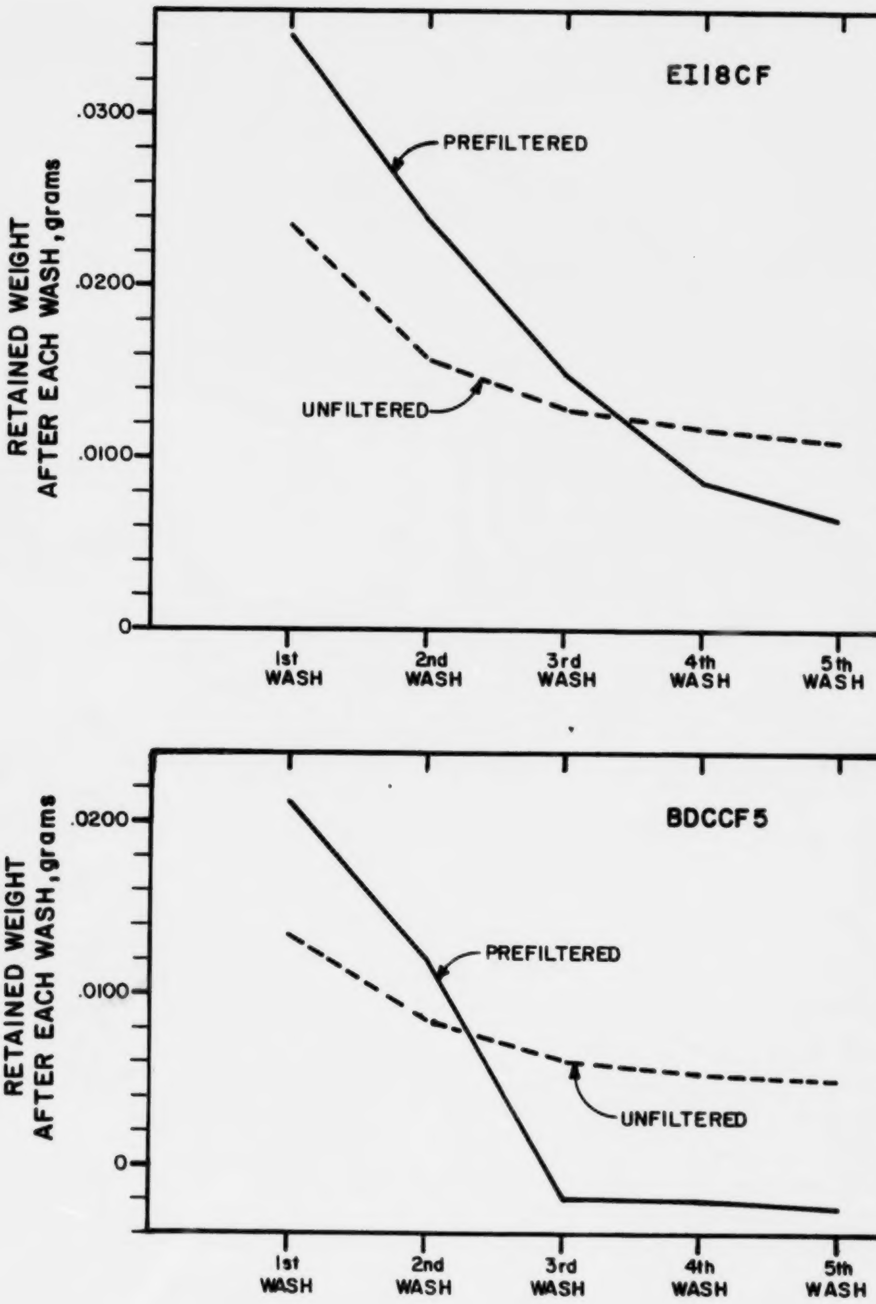
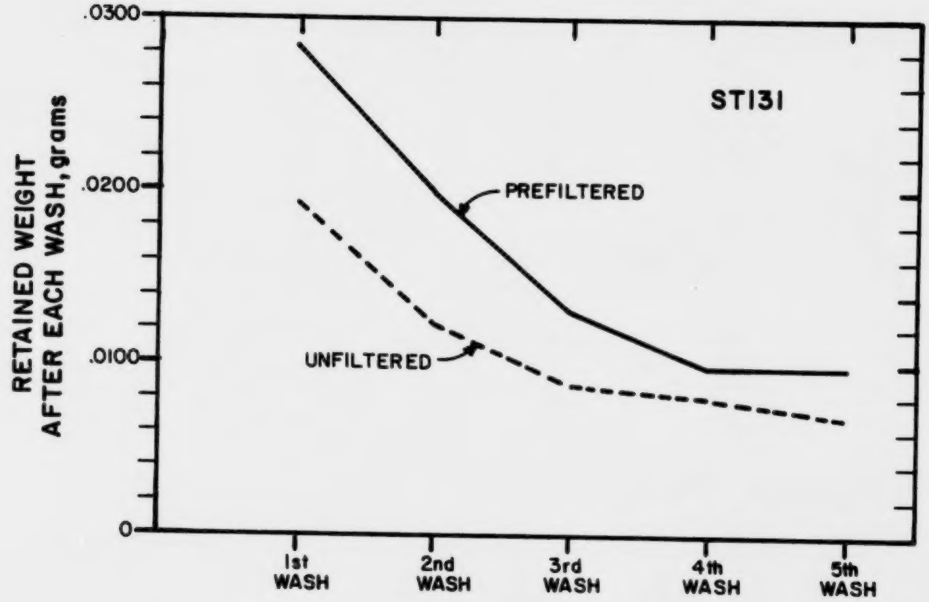


Figure 122. (Continued)



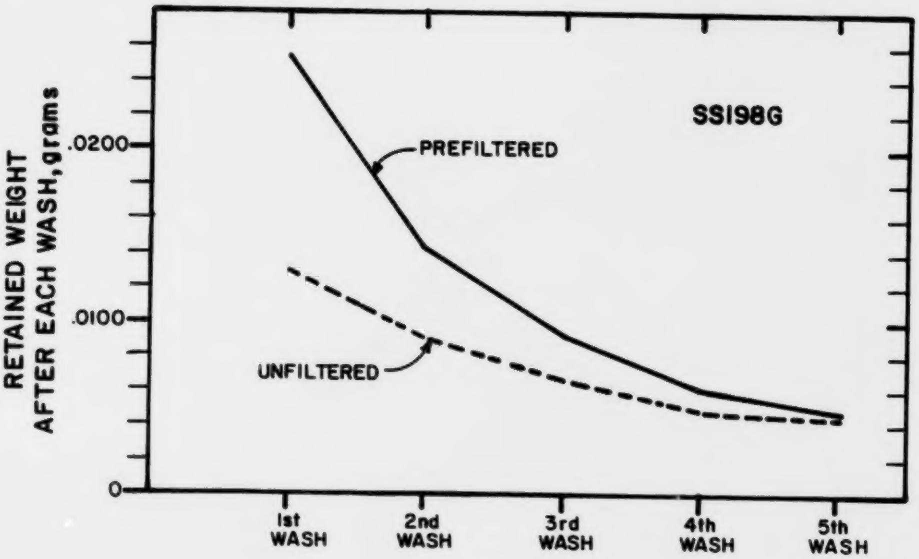


Figure 122. (Continued)

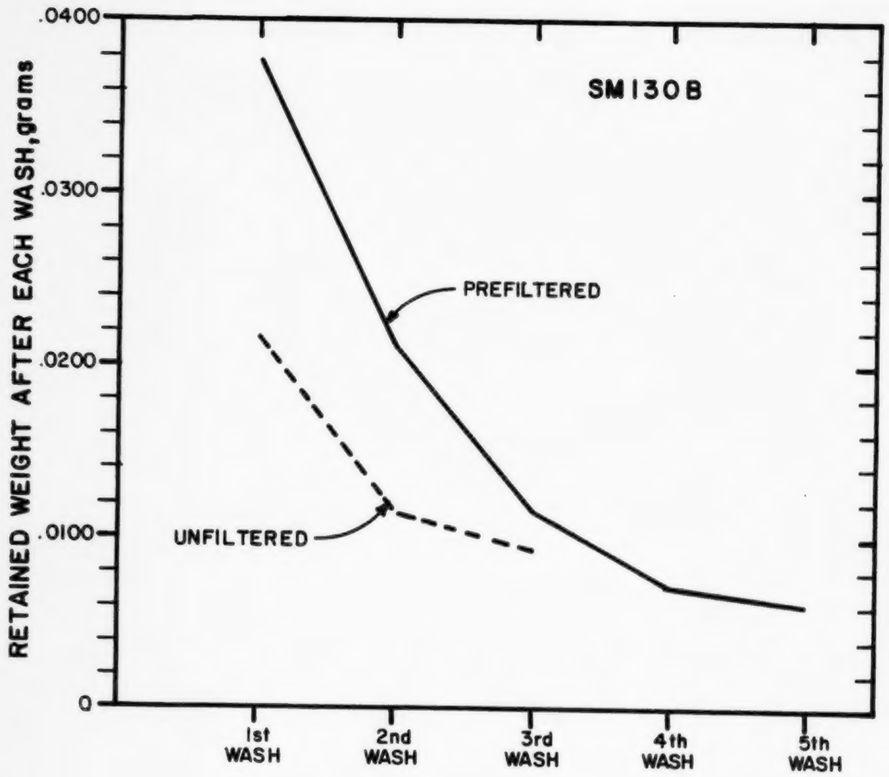


Figure 122. (Continued)

Results of Saved Filter Tests

All test results are listed in Tables 218, 219, 220, and 221. A summary is presented in Table 222.

The data in Table 222 show significant consistency in the mean amount of oil retained by filters used for IR-Oil tests on flotation effluent. The mean amount of oil retained by filters was equivalent to 1.9 to 3.2 mg/l in the brine, or equivalent to 2 to 4 percent of brine oil content.

On SS198G, saved filter tests was run on filters retained from some higher oil content brine samples taken upstream of the gravity separator. The data are in Table 218. One brine sample taken ahead of the gravity separator had 507 mg/l of oil, and the retained filter had 15 mg/l of oil. The percentage on the filter was still about 3 percent.

Conclusion of Saved Filter Tests

The amount of oil retained on filters from the IR-Oil test is much too small to explain why the IR-Oil test results are sometimes lower than the

TABLE 218. SS198G SAVED FILTER EXPERIMENT

			Oil, mg/l	
Day	Hour	Sample	Sample	Filter
Filters Saved Dry				
2	1300	9-10 IR	53	1.8
2	1300	9-10 GR	34	3.6
2	1300	9-1i IR	118	4.4
2	1300	8--i IR	237	7.7
3	0800	8--i GR	215	10.0
3	0800	8--i IR	313	10.0
3	1300	8--i IR	237	7.8
4	0800	8--i GR	299	10.3
4	0800	8--i IR	507	15.4
4	1300	8--i IR	406	10.2
5	0800	8--i IR	203	7.5
5	0800	8--i GR	170	7.3
5	1000	8--i IR	220	10.0
5	1000	8--i IR	245	10.2
5	1300	8--i IR	186	9.3
6	0800	8--i GR	180	6.3
6	0800	8--i IR	220	5.3
6	1300	8--i IR	224	5.1
7	0800	8--i GR	145	10.5
7	0800	8--i IR	182	12.9
7	1300	8--i IR	199	5.8
8	0800	8--i IR	224	4.7
8	0800	8--i GR	160	5.6
9	0800	8--i IR	207	5.6
9	0800	8--i GR	144	3.9
9	1300	8--i IR	232	3.4
10	0800	8--i IR	220	4.4
10	0800	8--i GR	157	4.4

TABLE 219. SM130B SAVED FILTER EXPERIMENT

Day	Hour	Sample	IR-Oil, mg/l Sample	IR-Oil, mg/l Filter
Filters Saved Dry				
1	1300	9--0 IR	64	2.2
2	1300	9--0 IR	62	1.8
3	1300	9--0 IR	74	2.4
4	1300	9--0 IR	39	2.0
5	1300	9--0 IR	54	1.7
6	2000	9--0 IR	44	1.7
7	1300	9--0 IR	35	2.2
8	1300	9--0 IR	35	2.2
9	1300	9--0 IR	35	1.8
10	1300	9--0 IR	27	1.1
2	1300	Blank		.2
4	1300	Blank		.1
5	1300	Blank		.1
6	1300	Blank		.1
7	1300	Blank		.1
Filters Saved In Freon				
1	0800	9--0 IR	66	2.1
2	0800	9--0 IR	54	3.6
3	0800	9--0 IR	86	3.2
4	0800	9--0 IR	52	1.7
5	0800	9--0 IR	40	1.5
6	0800	9--0 IR	33	1.5
7	0800	9--0 IR	40	2.0
8	1600	9--0 IR	40	2.1
9	0800	9--0 IR	36	2.7
10	0800	9--0 IR	46	1.8
1	1500	Blank		.4
2	0800	Blank		.3
3	0800	Blank		.3
4	0800	Blank		.2
5	0800	Blank		.2
6	0800	Blank		.3
7	0800	Blank		.1
8	0800	Blank		.3
9	0800	Blank		.3
10	0800	Blank		.3

EPA-287 (Cin.)
(4-76)

TABLE 220. EI18CF SAVED FILTER EXPERIMENT

Day	Hour	Sample	IR-Oil, mg/l Sample	IR-Oil, mg/l Filter
Filters Saved Dry				
1	0800	9--0 IR	59	2.1
2	1300	9--0 IR	78	1.2
3	0800	9--0 IR	102	2.0
4	1300	9--0 IR	116	2.4
5	0800	9--0 IR	155	.6
6	1300	9--0 IR	106	.6
7	0800	9--0 IR	50	4.4
8	1300	9--0 IR	33	1.5
9	0800	9--0 IR	35	1.4
10	1300	9--0 IR	35	3.2
4	1500	Blank		1.0
4	1500	Blank		.6
10	1300	Blank		.5
10	1300	Blank		.5
Filters Saved In Freon				
1	1300	9--0 IR	56	6.1
2	0800	9--0 IR	73	3.2
3	1300	9--0 IR	110	5.4
4	0800	9--0 IR	121	1.3
5	1300	9--0 IR	123	4.3
6	0800	9--0 IR	110	3.4
8	0800	9--0 IR	40	1.2
9	1300	9--0 IR	35	2.4
10	0800	9--0 IR	38	1.3
10	0800	Blank		.2
10	0800	Blank		.4

TABLE 221. BDCCF5 SAVED FILTER EXPERIMENT

Day	Hour	Sample	IR-Oil, mg/l Sample	IR-Oil, mg/l Filter
Filters Saved Dry				
1	1300	9--0 IR	50	2.3
2	1300	9--0 IR	126	2.8
3	1300	9--0 IR	139	6.8
4	1300	9--0 IR	25	.7
5	1300	9--0 IR	32	1.0
6	1300	9--0 IR	40	1.4
7	1300	9--0 IR	29	1.2
8	1300	9--0 IR	33	1.4
9	1300	9--0 IR	32	.8
10	1300	9--0 IR	33	1.2
2	1300	Blank		0
3	0800	Blank		.1
7	1300	Blank		.2
8	1300	Blank		0
10	1300	Blank		.1

filtered brine IR-Oil test results. A previously suggested possibility is that high results may be obtained on some filtered samples because of a water haze in the Freon when the absorbance is run since the test procedure used did not call for filtering the Freon extract for filtered brine oil tests.

SPECIAL OIL CONTENT TESTS

Special oil content tests were run on two platforms by modifying the standard acidification procedure. The Freon extraction was made first without acidifying the brine. IR-Oil and IR-Oil w/Silica Gel tests were run on this extract.

After the first extraction, the same brine sample was acidified in the regular manner and the Freon extraction was repeated. Oil content tests were also run on the second extract.

The test results are reported in Table 223 and 224 for Platforms BM2C and SS107. The general pattern is the same for both platforms, but more pronounced

TABLE 222. SUMMARY OF SAVED FILTER TESTS

Platform	Sample	Number of saved filters	Mean IR-Oil, mg/l Sample	Mean IR-Oil, mg/l Filter	Mean IR-Oil, mg/l Blank	Mean IR-Oil, mg/l Filter-blank	IR-Oil comparison of sample to filter %
Filters Saved Dry							
BDCCF5	9--0 IR	10	54	2.0	0.1	1.9	4
SM130B	9--0 IR	10	47	1.9	0.1	1.8	4
EI18CF	9--0 IR	10	77	1.9	0.6	1.3	2
SS198G	Various	28	233	7.4	-	-	3
Filters Saved In Freon							
SM130B	9--0 IR	10	49	2.2	0.3	1.9	4
EI18CF	9--0 IR	9	78	3.2	0.3	2.9	4

Note: 9--0 IR is the flotation effluent IR-Oil sample.

TABLE 223. BM2C FLOTATION EFFLUENT SPECIAL OIL TESTS

		Oil content, mg/l	
Test condition Test number	IR-Oil	Dispersed(1) oil	Soluble(1) oil
Brine Unacidified			
1	19	12	7
2	13	6	7
3	14	8	6
Mean	15	9	7
Brine Acidified			
1	34	0	34
2	34	0	34
3	41	0	41
Mean	36	0	36
Unacidified Plus Acidified			
1	53	12	41
2	47	6	41
3	55	8	47
Mean	52	9	43

(1) As determined by IR-Oil w/Silica Gel test.

Note: All numbers do not check because of rounding.

for BM2C. Only BM2C results are discussed.

The unacidified extraction results in a relatively low oil content value. The oil is indicated to be about equal in dispersed and soluble oil.

Acidifying the brine results in a substantially higher oil content value. All of the oil in the second extraction is indicated to be soluble.

One theory is that produced brine contains water soluble salts of naphthenic and other organic acids. The addition of acid to the brine in conducting the test then forms organic acids which are relatively soluble in Freon. These materials are then measured as oil. The special tests reported here generally confirm this theory.

TABLE 224. SS107 FLOTATION EFFLUENT SPECIAL OIL TESTS

Test condition Test number	Oil content, mg/l IR-Oil	 oil (1)	 oil (1)
Brine Unacidified			
1	5	0	5
2	6	0	6
3	4	0	4
Mean	5	0	5
Brine Acidified			
1	10	0	10
2	10	0	10
3	8	0	8
	9	0	9
Acidified Plus Unacidified			
1	15	0	15
2	16	0	16
3	12	0	12
Mean	14	0	14

(1) As determined by the IR-Oil w/Silica Gel test.

REFERENCES

1. Ferraro, J. M. and S. M. Fruh. "Study of Pollution Control Technology for Offshore Drilling and Production Platforms," Draft Report by Exxon Research and Engineering Company for EPA Industrial Environmental Research Laboratory, February 1978.

2. Myers, L. H., B. L. DePrater, T. E. Short, Jr. and B. B. Shunatona, Jr. "Offshore Crude Oil Wastewater Characterization Study," by EPA Robert S. Kerr Environmental Research Laboratory, August 1974.

3. Cross, E. F., E. C. Sebesta and W. T. Winn, Jr. "Determination of Best Practicable Control Technology Currently Available to Remove Oil From Water Produced With Oil and Gas," prepared by Brown & Root, Inc. for the Sheen Technical Subcommittee of the Offshore Operators Committee, March 1974.

4. Wyer, R. H., H. D. Van Cleave and K. E. Biglane. "Evaluation of Wastewater Treatment Technology for Offshore Oil Production Facilities," Proceedings of Seventh Annual Offshore Technology Conference, OTC 2232, May 5-8, 1975.

5. Tiratsoo, E. N. "Oilfields of the World," Scientific Press Limited, Beaconsfield, England, 1973. pp. 268.

6. Halbouty, M. T. "Salt Domes Gulf Region, United States and Mexico," Gulf Publishing Company, Houston, Texas, 1967. pp. 87.

7. APHA, AWWA, and WPCF. Standard Methods for the Examination of Water and Wastewater. "Method 502E." APHA, Washington, D.C., 14th Edition, 1976. pp. 520-521.

8. Gruenfeld, M. and U. Frank. "A Review of Some Commonly Used Parameters for the Determination of Oil Pollution," Proceedings of 1977 Oil Spill Conference, New Orleans, Louisiana, March 8-10, 1977. pp. 487-491.

9. Matovitch, M. A. "The Existence and Effects of Water Soluble Organic Components in Produced Brine," December 1976. Shell Oil Company Report submitted to Regional Administrator, EPA Region VI, May 26, 1978.

10. Miller, J. W. and C. I. Yaws. "Surface Tension of Liquids," Chemical Engineering, October 25, 1976. pp. 127-129.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

APPENDIX A

ANALYTICAL PROCEDURES

OIL AND GREASE INFRARED (OFFSHORE)

1.0 References

1.1 Environmental Protection Agency, 1979, "Methods for Chemical Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Environmental Research Center, Cincinnati, Ohio 45268, pages 413.2-1 through 413.2-3.

1.2 Operational Instructions, Model OCMA-200 Oil Content Analyzer, Horiba Instruments Incorporated, Houston, Texas 77092

Note: The technique detailed in this section follows the EPA Storet No. 00560 test exactly as given in reference 1.1 for extraction (sample size, extract volume and the number of extraction steps) only. Following step 7.6 (ref. 1.1) of Storet No. 00560, quantification in the field will employ Horiba OCMA-200 spectrometers (ref. 1.2).

2.0 Equipment and Reagents

2.1 Separatory funnel, 2000 ml, with Teflon stopcock.

2.2 Oil-in-water analyzer, Horiba OCMA-200.

2.3 Graduated cylinder, stoppered, 100 ml.

2.4 Syringes, glass, 10 µl.

2.5 Wash bottle, glass, 500 ml.

2.6 Freon TF (1,1,2 - trichloro - 1,2,2 - trifluoroethane).

2.7 Crude oil

2.8 Volumetric flask, 100 ml, 50 ml.

2.9 Hydrochloric acid, 6 N.

2.10 Pipet, 1 ml, 10 ml.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

2.11 Dispenser, glass, 50 ml.

2.12 Bottle, glass, 125 ml.

2.13 Bottle, glass, 1 liter.

2.14 Filter paper, Whatman No. 40, 11 cm.

2.15 Glass funnel

3.0 Calibration

3.1 Inject 10 ml of Freon TF into extraction chamber.

3.2 Turn extractor control to the open position.

3.3 Adjust zero control.

3.4 Prepare 100 ppm standard by injecting 10 microliters of oil into a 100 ml volumetric flask and dilute with Freon.

3.5 Inject 10 ml of 100 ppm standard into extraction chamber.

3.6 Open extraction cell and discharge sample.

3.7 Close extraction cell and refill with 10 ml of standard.

3.8 Adjust span for 100 ppm oil.

4.0 Field Procedure

4.1 Purge sample port.

4.2 Fill the bottle exactly to the 1.0 liter mark.

4.3 Add 5 ml hydrochloric acid to the sample bottle. After mixing the sample, check the pH by touching pH-sensitive paper to the cap to insure that the pH is 2 or lower. Add more acid, if necessary.

4.4 Rinse a clean 2000 ml separatory funnel with three successive 10 ml portions of Freon TF and drain. Discard rinsings after checking for contamination.

4.5 Pour the water sample into the separatory funnel.

4.6 Add 30 ml Freon to the sample bottle and rotate the bottle to rinse the sides. Transfer the solvent into the separatory funnel. Extract by shaking vigorously for 2 minutes. Allow the layers to separate.

4.7 Filter the solvent layer into a 100 ml volumetric flask through a funnel containing a solvent-moistened filter paper.

Note 1: An emulsion that fails to dissipate can be broken by pouring about 1 g sodium sulfate into the filter paper cone and draining the emulsion through the salt. Additional 1 g portions can be added to the cone as required.

4.8 Repeat (4.6 and 4.7) twice more with 30 ml portions of fresh solvent, combining all solvent in the volumetric flask.

4.9 Rinse the tip of the separatory funnel, filter paper, and the funnel with a total of 10-20 ml Freon and collect the rinsings in the flask. Dilute the extract to 100 ml, and stopper the flask.

4.10 Collect this extract in a 125 ml glass bottle, label and use for subsequent analysis onboard as well as ashore.

4.11 Dilute 10 ml of this extract to 100 ml using Freon TF.

4.12 Inject 10.0 ml of this Freon extract into analyzer.

4.13 Open extractor and discharge controls and discard effluent.

4.14 Refill analyzer with a fresh 10.0 ml aliquot of extract, open extractor and measure oil concentration.

4.15 Discharge sample and repeat step 4.14. Successive readings of each sample should agree within 5 ppm.

4.16 Retain remaining Freon extract for additional analysis in appropriately labeled glass bottle and seal.

4.17 If reading goes off scale (100 ppm), pipet 10.0 ml of extract into a 50 ml volumetric flask and dilute with Freon TF.

4.18 Determine oil concentration in diluted Freon extract as outlined in steps 4.12 - 4.15.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculation

6.1 The oil-in-water concentration with the first dilution only will be equal to the instrument reading if all volumes are taken as specified.

6.2 Oil-in-water concentration with any subsequent dilution:

ppm oil = ppm instrument x D

Where:

$$D = \frac{\text{total volume of dilution (ml)}}{\text{volume of Freon extract diluted (ml)}}$$

TYPING GUIDE SHEET

6.3 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section of the data sheet.

6.4 For final data report, convert oil measurement from ppm to mg/l by the formula:

oil (mg/l) = oil (ppm) x F

Where F = Correction factor, specific gravity of platform specific oil used for Horiba calibration, at 25°C.

7.0 Quality Control

7.1 Calibration must be performed at least once a day.

7.2 Successive readings of each sample should agree within 5 ppm. The average of the last two readings will be reported.

7.3 Repeat calibration procedure if a different container of Freon TF is used.

OIL AND GREASE GRAVIMETRIC (OFFSHORE AND ONSHORE)

1.0 References

1.1 Environmental Protection Agency, 1979, "Methods for Chemical Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Environmental Research Center, Cincinnati, Ohio 45268.

Note: The technique detailed in this section follows the EPA procedures as listed in reference 1.1 exactly as written.

2.0 Equipment and Reagents

2.1 Separatory funnel, 2000 ml.

2.2 Vacuum pump.

2.3 Flask, distilling, 125 ml.

2.4 Filter paper, Whatman No. 40, 11 cm.

2.5 Funnel, glass.

2.6 Hydrochloric acid, 6 N.

2.7 Freon TF (1,1,1 - trichloro - 1,2,2 - trifluoroethane).

2.8 Sodium sulfate, anhydrous crystal.

EPA-287 (Cin.)
(4-76)

2.9 Bottle, glass, 1000 ml, 125 ml.

2.10 Syringe, glass, 10 ml.

2.11 Water bath, variable temperature.

3.0 Calibration

3.1 Not applicable.

4.0 Field Procedure

4.1 Purge sample port.

4.2 Fill a 1 liter bottle to the 1.0 liter volume mark.

4.3 Add 5 ml 6N hydrochloric acid.

4.4 Pour the sample into a separatory funnel.

4.5 Add 30 ml Freon TF to the sample bottle and rotate the bottle to rinse the sides.

4.6 Transfer the solvent to the separatory funnel, stopper and shake vigorously for 2 minutes.

4.7 Filter the solvent layer into a 125 ml bottle through a funnel containing solvent-moistened filter paper. An emulsion present in the extract may be broken by adding a gram of sodium sulfate into the filter paper cone.

4.8 Repeat steps 4.4 - 4.7 twice more, with additional portions of fresh solvent, combining all extracts in a glass bottle.

4.9 Rinse the tip of the separatory funnel, filter paper and funnel with 10-20 ml Freon and collect the rinsings in the 125 ml bottle. Seal, label and place in storage container for shipment ashore.

5.0 Laboratory Procedure

5.1 Extract 3 1-liter deionized water samples, steps 4.1 - 4.8, using Freon TF from the same batch which was used in the field.

5.2 Transfer the Freon extract to a tared distilling flask.

5.3 Rinse the glass bottle with 10 ml Freon and add washings to the flask.

5.4 Evaporate the solvent in a water bath at 70°C. Dry by placing the flask on a covered 80°C water bath for exactly 15 minutes.

5.5 Draw N_2 through the flask by means of an applied vacuum for 1 minute. Watch the neck of the flask for neck ring condensation which would trap solvent and produce a heavy weighing.

5.6 Cool in desiccator for 30 minutes and weigh.

6.0 Calculations

6.1 Oil in water concentration using gravimetric procedure:

$$\text{ppm (mg/l) oil} = \frac{R-B}{V}$$

Where: R = residue, gross weight of flask minus tare weight (milligrams)

B = blank, residue of equivalent volume of solvent (milligrams)

V = sample volume (liters)

6.2 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 A minimum of 3 blanks will be run per set of samples from one platform.

7.2 When a new container of Freon TF is used in the field, a new set of blanks is required.

7.3 The analytical balance must have been calibrated and verified accurate to within 0.1 mg.

PARTICLE SIZE DISTRIBUTION (OFFSHORE)

Equipment, personnel, technique, as well as data reduction, to be provided by Rockwell International.

Note: Each time a particle size distribution test is run an IR-Oil test, an IR-Oil with silica gel test, and a filtered brine test will be run. The procedures for these tests appear elsewhere in this document.

TEMPERATURE MEASUREMENT (OFFSHORE)

1.0 Reference

1.1 American Society for Testing and Materials, "1974 Annual Book of ASTM Standards, Part 24, Petroleum Products and Lubricants,"

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

DROPPED HEAD; BEGIN SECTIONS HERE

2.0 Equipment

2.1 Thermometer, dial type, 0-100°C.

2.2 Thermometer, mercury, 0-100°C.

2.3 Bottle or suitable container for sample collection.

3.0 Calibration

3.1 At a minimum frequency of once a day, place both the dial type and mercury thermometers in a bottle full of sample water.

3.2 Allow 1 minute for the thermometers to equilibrate.

3.3 Compare and note any differences in the temperature readings using the mercury thermometer as the standard.

4.0 Field Procedure

4.1 Allow about 5 liters of effluent to flow out of the system at some convenient rate.

4.2 Collect about 1 liter in a bottle and immediately insert the dial thermometer.

4.3 Wait 1 minute until the thermometer has equilibrated and read the temperature.

4.4 If the sample site has a temperature well, place the thermometer directly into the port, wait 1 minute and read the temperature.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculations

6.1 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 All dial thermometer readings will be corrected based upon deviations from a mercury thermometer meeting National Bureau of Standards specifications.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

pH (OFFSHORE)

1.0 Reference

1.1 American Society for Testing and Materials, "1978 Annual Book of ASTM Standards, Part 31, Water," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The technique detailed in this section follows "Method B - Routine or Continuous Measurements pH" (Reference 1.1). A combination electrode (Corning No. 476051) will be used, which is Sodium-compensated in the pH range 1-10. If higher pH (10) is encountered, a high alkaline combination electrode (IL No. 14063) will be used.

2.0 Equipment and Reagents

2.1 pH meter, battery operated.

2.2 Electrode, combination.

2.3 Standard buffers, pH 4.00, 6.86, 9.18 at 25°C.

2.4 Deionized water.

2.5 Kim-Wipes or equivalent.

2.6 Bottle or other suitable container for sample collection.

3.0 Calibration

3.1 Calibrate the instrument immediately prior to each use.

3.2 Immerse the combination electrode (Corning 476051) into pH 7.00 buffer.

3.3 Adjust temperature knob to the previously determined temperature of the sample.

3.4 Adjust the calibrate knob to pH 7.00 reading.

3.5 Remove electrode, rinse with deionized water and wipe clean.

4.0 Field Procedure

4.1 This measurement is made in conjunction with the temperature determination.

4.2 Allow about 5 liters of effluent to flow out of the system at some convenient rate.

4.3 Collect about 1 liter of sample and proceed with the temperature

EPA-287 (Cin.)
(4-76)

measurement, if required.

4.4 Immerse combination electrode in sample and agitate gently for 30 seconds.

4.5 Read pH after steady state has been achieved.

4.6 Remove electrode, rinse with deionized or clean tap water and wipe clean.

4.7 If the pH is 10, change to the high alkaline electrode (IL-14063), calibrate using the pH 9.18 buffer and repeat steps 4.3-4.5.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculations

6.1 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Instrument will be calibrated prior to each use.

7.2 Perform a response verification of electrode every other day using all three buffers. Verify Nernst response of the combination electrode using the slope equation given in the following table. Results should be within 95-99% agreement, or the electrode is to be replaced.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

CONSTANTS FOR CALCULATION OF RESPONSE EQUATION SLOPE
F/(2.3026 RT)[A]

Temperature °C	F/(2.3026 RT) V^{-1}
0	18.4512
5	18.1195
10	17.7996
15	17.4907
20	17.1924
25	16.9041
30	16.6253
35	16.3555
40	16.0944
45	15.8414
50	15.5963
55	15.3587
60	15.1282
65	14.9045
70	14.6873
75	14.4764
80	14.2714
85	14.0722
90	13.8784
95	13.6899

A. The above data were calculated using a precise value of the logarithmic conversion factor (2.302585) and values of the fundamental constants.

$F = 96\,487.0 C/eq$
$R = 8.31433$ J/K mol
$T = 273.15 + °C$

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

BOILING RANGE DISTRIBUTION (ONSHORE)

1.0 Reference

1.1 American Society for Testing and Materials "1974 Annual Book of ASTM Standards Part 24, Petroleum Products and Lubricants," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The technique detailed in this section follows ANSI/ ASTM D22887-73 Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography exactly as given in reference 1.1.

2.0 Equipment and Reagents

2.1 Perkin-Elmer, Sigma 2 Gas Chromatograph equipped with a flame ionization detector.

2.2 Perkin-Elmer, Sigma 10 Chromatography Data Section.

2.3 Calibration mixture of a homologous series of n-alkanes from C-12 through C-32, plus o-xylene, n-butylbenzene, tri-isopropylbenzene, n-decylbenzene and tetrodecylbenzene.

2.4 Syringe, 10 μl.

2.5 Miscellaneous laboratory glassware.

3.0 Calibration

3.1 A mixture of hydrocarbons of known boiling points covering the boiling range of the sample shall be prepared according to reference 1.1.

3.2 At least one compound in the mixture must have a boiling point lower than the initial boiling point of the sample.

3.3 If the sample contains significant quantities of n-paraffins which can be identified on the chromatogram, these peaks will be used as internal boiling point calibrations.

3.4 Run this calibration mixture in exactly the same manner as the crude oil sample is to be done. Record the retention time of each component. Plot retention times vs. atmospheric boiling points to obtain the calibration curve. From this curve, assign boiling temperatures to each of the intervals at which area measurements are made.

3.5 The calibration curve must be verified each time the determination is made.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

4.0 Field Procedure

4.1 Collect a sample of crude oil for boiling range determination from the platform crude oil storage tank in duplicate, clean 125 ml glass bottles equipped with Teflon-lined screw caps, label and store in shipping containers for subsequent shipment ashore. Duplicate samples are to be collected to provide a backup sample in case of possible breakage.

5.0 Laboratory Procedure

5.1 Run the chromatograph through the temperature programming sequence to verify accurate instrument settings.

5.2 Run the calibration mixture through the gas chromatograph analysis to verify stable operating conditions and accurate data recording.

5.3 Run the crude oil sample from one of the two samples for each platform through the gas chromatograph analysis.

5.4 Record the peaks at a sensitivity setting that allows the maximum peak height compatible with data station recording capabilities.

5.5 The data station will output time, integrated area for each peak, total cumulative area, and amount at time intervals considerably less than 1% of the total retention time equivalent to 583°C. Time and cumulative area at 0.5 and 99.5% of total area will be obtained from these data.

6.0 Calculations

6.1 Record the time and cumulative area count at 0.5% of the total area. Mark this point as the intiial boiling point of the sample (IBP).

6.2 Record the time and cumulative area count at 99.5% of the total area. Mark this point as the final boiling point of the sample (FBP).

6.3 Divide the cumulative area at each interval between IBP and FBP by the total cumulative area counts. This will give the percent of sample recovered at each interval.

6.4 Tabulate the percent recovered at each interval and the boiling temperature assigned to that interval from the calibration procedure 3.0.

7.0 Quality Control

7.1 The gas chromatograph detector used must have sufficient sensitivity to detect 1.0 percent dodecane with a peak height of at least 10% of full scale on the recorder.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

7.2 When operating at this sensitivity level, detector stability must be such that a baseline drift of not more that 1% per hour is obtained.

7.3 The detector must be capable of continuous operation at a temperature equivalent to the maximum column temperature employed, and it must be connected to the column without inducing cold spots.

7.4 The gas chromatograph must be capable of program temperature operation over a range sufficient to establish a retention time of at least 1 minute for the IBP and to elute the entire sample.

7.5 The programming rate must be sufficiently reproducible to obtain retention time repeatability of 0.1 minute (6 seconds) for each component in the calibration mixture.

7.6 The sample inlet system must be capable of operating continuously at a temperature equivalent to the maximum column temperature employed, and be connected to the column without cold spots.

7.7 A recorder must be used to obtain a trace of the compounds eluting off the column with a full-scale response time of 2 seconds or less.

7.8 Data must be collected by electronic integration. A timing device is to be used to cause the integrator to print out at equal time intervals.

7.9 Gas chromatographs must be equipped with constant flow controllers capable of holding carrier gas flow constant to 1% over the full operation temperature range.

7.10 Resolution calculated from the distance between C-16 and C-18 n-paraffin peaks must be at least 3 and not more than 8 when calculated in the normal manner.

SPECIFIC GRAVITY, OIL AND WATER (OFFSHORE)

1.0 Reference

1.1 American Society for Testing and Materials, "1974 Annual Book of ASTM Standards, Part 23, Petroleum Products and Lubricants," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The technique detailed in this section follows the procedures of ASTM D 1298-67 (1972) as listed in reference 1.1 exactly as written.

2.0 Equipment

2.1 Hydrometers, ASTM 82H-88H, 111H, 112H.

2.2 Hydrometer cylinder.

2.3 Thermometer, mercury, 0-100°C.

3.0 Calibration

3.1 Specific gravity measurements in an opaque liquid require a correction factor since hydrometers are calibrated to read at the principal surface of the liquid.

3.2 For a particular hydrometer, record the maximum height above the principal surface of the liquid to which the liquid rises on the hydrometer scale when the hydrometer is immersed in a transparent oil having a surface tension similar to that of the sample.

4.0 Field Procedure

4.1 Purge sample port.

4.2 Fill hydrometer cylinder from sample port without splashing, to avoid the formation of air bubbles.

4.3 Insert a thermometer into the sample; wait until the sample reaches equilibrium. Record the temperature after gently stirring the sample with the thermometer.

4.4 Lower the hydrometer into the sample. Take care to avoid wetting the stem above the level to which it will be immersed in the liquid.

4.5 Depress the hydrometer about two scale divisions into the liquid, and with a slight spin, release it.

4.6 When the hydrometer has come to rest, floating freely away from the walls of the cylinder, estimate the scale reading to the nearest 0.0001 sp gr.

4.7 With an opaque liquid take a reading by observing, with the eye slightly above the plane of the surface of the liquid, the point on the hydrometer scale to which the sample rises. Correct this reading based upon the meniscus calibration for the particular hydrometer being used.

4.8 Immediately after observing the hydrometer scale value, stir the sample with the thermometer and record the temperature. Should this temperature differ from the previous reading by more than 0.5°C, repeat the hydrometer and thermometer readings until the temperature becomes stable with 0.5°C.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculations

6.1 Report specific gravity, with meniscus calibration where necessary. Report temperature of sample at time specific gravity was measured.

6.2 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Sample must reach thermal equilibrium, less than 0.5°C variation in two successive readings, before an accurate specific gravity measurement can be made.

7.2 Record the temperature at which the specific gravity determinations were made.

WATER CUT (OFFSHORE)

1.0 Reference

1.1 American Society for Testing and Materials, "1974 Annual Book of ASTM Standards, Part 24, Petroleum Products and Lubricants," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The technique detailed in this section follows the procedures of ASTM D 1796-68 (1973) as listed in reference 1.1 without modification.

2.0 Equipment and Reagents

2.1 Centrifuge, hand powered.

2.2 Centrifuge tube, API, 12.50 ml.

2.3 Toluene (water-saturated).

2.4 Nalco 103 (or Visco 103) demulsifier.

3.0 Calibration

3.1 Not required.

4.0 Field Procedure

4.1 It is recommended that the centrifuge tube be filled directly from the circulating stream. If this is not possible, transfer the sample in a bottle and shake thoroughly immediately before filling the centrifuge tube. Purge sample port prior to filling tube.

4.2 Fill each of two centrifuge tubes to the 50% mark with sample to be tested.

4.3 Add solvent to the 100% mark and 1 drop of demulsifier.

4.4 Stopper the tubes and shake until the contents are thoroughly mixed.

4.5 Place tubes in the centrifuge and revolve for 3 to 10 minutes, depending upon the separation character of the mixed phases.

4.6 Remove the tubes and record the combined volume of water and sediment in each tube to the nearest 0.1%.

4.7 Replace the tubes in the centrifuge and revolve again 3 to 10 minutes.

4.8 Again record the combined water and sediment. If there is a difference of more than 0.2% between the first and second readings, continue centrifuging until two consecutive readings check within 0.2%.

4.9 The sum of the final readings on the two 12.50 ml centrifuge tubes represents the volume percentage of water and sediment in the sample.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculations

6.1 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Repeat centrifuging samples until consecutive readings agree within 0.2%.

SUSPENDED SOLIDS (OFFSHORE AND ONSHORE)

1.0 References

1.1 Environmental Protection Agency, 1979, "Methods for Chemical Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Environmental Research Center, Cincinnati, Ohio 45268.

1.2 American Society for Testing and Materials, "1978 Annual Book of ASTM Standards, Part 31, Water," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The techniques detailed in this section follow the procedures given in reference 1.1 for total non-filtereable residue (Storet No. 00530). Quality control procedures are taken from the Standard Test Method D 1888-67 (1974) Particulate and Dissolved Matter in Water, as given in reference 1.2.

2.0 Equipment

2.1 Filter holder, inline 47 mm.

2.2 Filters, glass fiber, 47 mm, preashed, preweighed and packaged in individual petri dishes.

2.3 Graduated cylinder, 1 liter.

2.4 Vacuum pump, hand operated.

2.5 Filter flask, 1 liter.

2.6 Hydrochloric acid 6N.

2.7 Freon TF (1,1,2 - trichloro - 1,2,2 - trifluoroethane).

2.8 Balance, analytical, 0.1 mg.

2.9 Deionized water.

2.10 Forceps.

3.0 Calibration

3.1 Not applicable.

4.0 Field Procedure

4.1 Rinse empty filter holder with deionized water.

4.2 Insert preweighed filter into holder using forceps.

4.3 Purge sample port.

4.4 Attach inlet side of loaded filter holder to sampling port.

4.5 Turn on flow and collect filtered effluent into the 1 liter filter flask applying a suction with the hand vacuum pump.

4.6 Continue filtration until flow rate has decreased sufficiently to indicate the filter is beginning to clog.

4.7 Disconnect the filter holder and reconnect it to a glass funnel.

4.8 Filter 50 ml of prefiltered (0.45 micron) deionized water through the filter holder to wash the glass fiber filter.

4.9 Disconnect the filter holder, remove filter and replace it in the petri dish, inventory and refrigerate prior to shipment.

4.10 Record the volume of water filtered, and number of filter.

4.11 Store filter holder in cleaning solution.

5.0 Laboratory Procedure

5.1 Place glass fiber filter in vacuum desiccator and dry to constant weight.

5.2 Weight filter to the nearest milligram and record as total suspended solids, gross weight.

5.3 Wash filter with 100 ml Freon TF and vacuum dry.

5.4 Weigh filter and record as organic soluble suspended solids, gross weight.

5.5 Wash filter with 100 ml 6N HCl and again vacuum dry.

5.6 Weigh filter and record as acid soluble suspended solids, gross weight.

6.0 Calculations

6.1 Total Suspended Solids

$$\text{TSS (mg/l)} = \frac{[R - (T - B)] \times 1000}{V}$$

Where: R = residue + filter (grams)

T = tare weight of filter (grams)

B = blank filter weight loss after drying (grams)

V = volume filtered (liters)

6.2 Freon Soluble Suspended Solids

$$T_o = \frac{(R - R_o - B_o) \times 1000}{V}$$

Where: R_o = residue + filter after solvent wash (grams)

B_o = blank filter weight loss after solvent wash (grams)

6.3 Freon Insoluble Residue

$T_I = TSS - T_o$

6.4 Acid Soluble Suspended Solids

$$T_a = \frac{(R_o - R_a - B_a) \times 1000}{V}$$

Where: R_a = residue + filter acid wash (grams)

B_a = blank filter weight loss after acid wash (grams)

6.5 Fixed Suspended Solids

$FSS = TSS - T_o - T_a$

6.6 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

6.7 The test results for suspended solids will be reported as follows in mg/l: Total, Freon Soluble, Freon Insoluble, Fixed, and Acid Soluble.

6.8 Process one blank filter through steps 5.1 - 5.8 for every 10 samples.

SURFACE TENSION, OIL AND WATER (OFFSHORE)

1.0 Reference

1.1 American Society for Testing and Materials, "1978 Annual Book of ASTM Standards, Part 31, Water," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The test method detailed in this section follows procedures for the Standard Test Method D 1590-60 (1977) for Surface Tension of Water exactly as cited in reference 1.1.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

2.0 Equipment and Reagents

2.1 Tensiometer, Du Nouy ring.

2.2 Vibration-free support.

2.3 Weights, analytical.

2.4 Propane torch.

2.5 Evaporating dish, 100 ml.

2.6 Chromic - sulfuric acid cleaning solution.

2.7 Methyl ethyl ketone

2.8 Hydrochloric acid, 2N.

3.0 Calibration

3.1 Level the tensiometer and adjust the length of the torsion arm by means of weights and the adjustments so that each unit of the graduated scale represents a pull on the ring of 1 dyne/cm.

3.2 From the calibration weight and instrument reading, calculate the grams of pull on the ring represented by each scale division. Use this value for calculating the conversion factor, F, which is employed to give corrected surface tension values.

4.0 Field Procedure

4.1 Collect the sample using only thoroughly cleaned glass-stoppered vessels (Note 1). Purge sample ports prior to collection.

4.2 After the tensiometer has been calibrated, check the level and insert the freshly cleaned platinum ring (Note 2).

4.3 Level the plane of the ring and set the measuring dial at zero.

4.4 Adjust the ring to the zero position.

4.5 Place the sample to be tested in the thoroughly cleaned evaporating dish (Note 1) on the sample platform.

4.6 Raise the sample platform by means of the adjusting screw until the ring is completely submerged, but not to exceed 3 mm.

4.7 Permit the sample surface to age for 30 seconds.

4.8 Lower the platform slowly by means of the adjusting screw, at the same time increasing the torque of the ring system by means of the dial adjustment. These two simultaneous adjustments must be

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

carefully made so that the ring system remains constantly in the zero position.

4.9 Record the dial reading when the ring breaks free of the sample film. Complete the break within 60 seconds after starting measurement.

4.10 Measure and report temperature of test samples immediately after readings are taken.

4.11 Samples showing evidence of free oil will be settled for 30 minutes under susceptibility to separation test conditions. The surface tension test will be run on the settled brine.

4.12 Extra samples will be taken when oil content is high (400 mg/l) when a regular sample is not scheduled.

Note 1: The recommended cleaning procedure comprises a 1-hour soak in chromic-sulfuric acid, five deionized water rinses and overnight storage in deionized water. Glassware used for this test should be kept segregated and stored in deionized water.

Note 2: For each sample, the platinum ring must be freshly cleaned by immersing in methyl ethyl ketone, permitted to dry, immersing in hydrochloric acid (2N) and rinsing thoroughly with deionized water. The ring is again immersed in methyl ethyl ketone, permitted to dry and then heated to a white heat in the oxidizing portion of a gas flame. Successive measurements on the same sample will require cleaning and flaming the ring for each determination.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculation

6.1 Calculate the corrected surface tension as follows: Surface tension, dynes/cm = PF

Where: P = scale reading in dynes/cm when film breaks

F = correction factor

6.2 The values of F are based upon two calculated values, $R^3 (D-d)/M$ and R/r. These parameters are used with a standard table to obtain the correction factor F.

Where: R = mean radius of the ring (cm)

EPA-287 (Cin.)
(4-76)

r = radius of the wire in the ring (cm)

D = density of liquid

d = density of air saturated with vapor of liquid

M = weight of liquid raised above free surface of the liquid (equivalent to dial reading multiplied by factor derived in 3.2).

6.3 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Make at least two measurements each on separate sample portions, making additional measurements in accordance with the magnitude of the overall variation of the first two.

7.2 The precision of this method is 0.3 dyne/cm.

7.3 Record calibration of each tensiometer in the calibration log.

SILICA GEL ADSORPTION (OFFSHORE)

1.0 Reference

Standard Methods for the Examination of Water and Wastewater. 14th Edition, 1975. American Public Health Association, American Water Works Association, Water Pollution Control Federation. American Public Health Association, 1015 Eighteenth Street NW, Washington, DC 20036.

Note: The techniques detailed in this section follow Standard Method, 502 E., Hydrocarbons, exactly as given in reference 1.1.

2.0 Equipment and Reagents

2.1 Oil-in-water analyzer, Horiba OCMA-200.

2.2 Syringe, glass 10 µl, 10 ml.

2.3 Freon TF (1,1,2 - trichloro - 1,2,2 - trifluoroethane).

2.4 Silica gel, 100 - 200 mesh, deactivated with 2% water.

2.5 Magnetic stirrer with Teflon stirring bar.

2.6 Volumetric flask, 100 ml.

2.7 Bottles, glass, 125 ml.

3.0 Calibration

3.1 Inject 10 ml of Freon TF into extraction chamber.

3.2 Turn extractor control to the open position.

3.3 Adjust zero control.

3.4 Prepare 100 ppm standard by injecting 10 microliters of oil into a 100 ml volumetric flask and dilute with Freon.

3.5 Inject 10 ml of 100 ppm standard into extraction chamber.

3.6 Open extraction cell and discharge sample.

3.7 Close extraction cell and refill with 10 ml of standard.

3.8 Adjust span for 100 ppm oil.

4.0 Field Procedure

4.1 The diluted extract analyzed for IR determination in produced water is to be treated and analyzed as follows:

4.2 Transfer the extract to a 100 ml volumetric flask.

4.3 Add 3 grams of silica gel.

4.4 Insert magnetic stirring bar and agitate at a rate sufficient to cause continuous convection of the silica gel.

4.5 After 10 minutes, stop the stirrer and allow the silica gel to settle completely.

4.6 Carefully withdraw 10 ml of Freon extract with a syringe and inject it into the analyzer.

4.7 Open extractor and discharge controls and discard effluent.

4.8 Refill analyzer with a fresh 10 ml aliquot of extract, open extractor and measure oil concentration.

4.9 Discharge sample and repeat steps 4.4 to 4.8. Successive readings of each sample should agree with 5 ppm.

4.10 Retain remaining Freon extract in appropriately labeled glass bottle and seal.

4.11 If reading goes off scale (100 ppm) pipet 10.0 ml of extract into 50 ml volumetric flask and dilute with Freon TF.

4.12 Determine oil concentration in diluted extract as outlined in 4.6-4.9.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculation

6.1 Oil-in-water concentration with silica gel with no Freon extract dilution:

ppm oil (silica gel) = ppm (instrument reading)

6.2 Oil-in-water concentration with silica gel with dilution, ppm oil

$$\text{(silica gel)} = \text{ppm} \times D \times \frac{E}{S}$$

Where: $D = \dfrac{\text{total volume of dilution (ml)}}{\text{volume of extract diluted (ml)}}$

E = volume of Freon extract treated (ml)

S = volume of sample (ml)

6.3 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

6.4 For final data report, convert oil measurement from ppm to mg/l by the formula:

oil (mg/l) = oil (ppm) x F

Where: F = correction factor, specific gravity of platform specified oil used for Horiba calibration at 25°C.

7.0 Quality Control

7.1 Calibration of the Horiba must be performed at least once a day.

7.2 Successive readings of each sample should agree with 5 ppm. The average of the last two readings will be reported.

7.3 Repeat calibration procedure if a different container of Freon TF is used.

7.4 The silica gel must be well sealed during storage to prevent moisture accumulation.

7.5 If adsorption removes 30% of the oil, redo the analyses on the

TYPING GUIDE SHEET
EPA-287 (Cin)
(4-76)

previously tested Freon extract, if enough extract remains. If 1-5% reduction occurs after the second treatment, use this second number.

VISCOSITY (ONSHORE)

1.0 Reference

1.1 American Society for Testing and Materials, "1974 Annual Book of ASTM Standards, Part 23, Petroleum Products and Lubricants," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

Note: The method detailed in this section follows the Standard Test Method (D 445-74) Kinematic Viscosity of Transparent and Opaque Liquids exactly as given in reference 1.1.

2.0 Equipment

2.1 Viscometer, Cannon-Fenske, ASTM-50, 100, 200, 350, calibrated.

2.2 Stopwatch.

2.3 Constant-temperature bath.

2.4 Hydrometer.

2.5 Bottle, glass 500 ml.

3.0 Calibration

3.1 Only Cannon-type CFRC viscometers which have been calibrated by the manufacturer will be used.

4.0 Field Procedure

4.1 Purge sample port.

4.2 Fill sample bottle, seal, label, inventory and pack for shipment.

5.0 Laboratory Procedure

5.1 Select a clean, dry calibrated viscometer that will give a flow time greater than 200 seconds.

5.2 To charge the viscometer, invert the viscometer and apply suction to the mounting tube (large diameter) with the upper vent tube (small diameter) in the liquid sample.

5.3 Draw the sample to the second timing mark.

5.4 Mount the viscometer upright in the constant temperature bath at

TYPING GUIDE SHEET

same temperature with which it was calibrated, keeping the mounting tube vertical.

5.5 Allow the viscometer to remain in the constant temperature for 10 minutes to ensure that the sample reaches temperature equilibrium.

5.6 Use vacuum to draw the sample through the bulb to about 5 mm above the upper time mark.

5.7 Release the vacuum, and allow the sample to flow by gravity.

5.8 Measure, to the nearest 0.1 second, the time required for the leading edge of the meniscus to pass from the first timing mark to the second. If this flow time is less than 200 sec., select a smaller capillary viscometer and repeat 5.2-5.8.

5.9 Repeat 5.6-5.8, making duplicate flow time measurements. If the two measurements agree within 0.2%, use the mean for calculating the kinematic viscosity.

6.0 Calculation

6.1 Calculate the kinematic viscosity, by the following:

$$\gamma = C\,t$$

Where: γ = kinematic viscosity, cs

C = calibration constant of the viscometer

t = flow time, seconds

6.2 Calculate the viscosity, N, by the following:

$$N = p\,\gamma$$

N = dynamic viscosity, cp

p = density, g/cm^3, at the same temperature used for measuring the flow time t.

6.3 Report test results for both kinematic and dynamic viscosity rounded to the nearest one part per thousand.

6.4 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Use only Cannon-type CFRC viscometers which have been calibrated

EPA-287 (Cin.)
(4-76)

by the manufacturer.

7.2 Duplicate flow time measurements will be made. Only duplicate measurements within 0.2% agreement will be acceptable.

SUSCEPTIBILITY TO OIL SEPARATION (OFFSHORE)

1.0 Reference

1.1 American Petroleum Institute, 1968, "API Recommended Practice for Analysis of Oil-Field Water," American Petroleum Institute, Division of Production, 300 Corrigan Tower Bldg., Dallas, Texas 75201.

Note: The techniques detailed in this section follow the Determination of Susceptibility to Oil Separation (API Method 734-53) as listed in reference 1.1 for the 30 minute settling time. Other settling times will be employed to provide additional data.

2.0 Equipment

2.1 6 separatory funnels, 2 liter.

2.2 Funnel support rack.

2.3 Bottle, glass, 1000 ml.

2.4 Oil-in-water analyzer, Horiba OCMA-200.

2.5 Graduated cylinder, stoppered, 100 ml.

2.6 Syringe, glass, 10 µl.

2.7 Freon TF (1,1,2 - trichloro - 1,2,2 - trifluoroethane).

3.0 Calibration

3.1 Inject 10 ml of Freon TF into extraction chamber.

3.2 Turn extractor control to the open position.

3.3 Adjust zero control.

3.4 Prepare 100 ppm standard by injecting 10 microliters of oil into a 100 ml volumetric flask and dilute with Freon.

3.5 Inject 10 ml of 100 ppm standard into extraction chamber.

3.6 Open extraction cell and discharge sample.

3.7 Close extraction cell and refill with 10 ml of standard.

3.8 Adjust span for 100 ppm oil.

4.0 Field Procedure

4.1 Note and record sample stream temperature. Purge sample port.

4.2 Collect one "initial" sample in a 1.0 liter bottle.

4.3 Collect 6 two-liter samples in identical 2 liter separatory funnels. As collection of each sample is completed, record the time and place the separatory funnel in the rack. The order of taking samples in terms of settling times will be the 0, 120, 60, 30, 15, 5, 2 and 0 minute samples.

4.4 After collection of the 2-minute sample, collect a "final" 1.0 liter sample in a 1.0 liter bottle.

4.5 Withdraw 1-liter samples from successive separatory funnels at intervals of 2, 5, 15, 30, 60, 120 minutes after collection.

4.6 Measure and record the temperature of the water remaining in each separatory funnel after the 1-liter aliquot is taken.

4.7 Add 5 ml 6N hydrochloric acid to each sample.

4.8 Pour the first sample into a 2-liter separatory funnel.

4.9 Add 25 ml Freon TF to the sample bottle and rotate the bottle to rinse the sides.

4.10 Transfer the solvent to the separatory funnel, stopper and shake vigorously for 2 minutes.

4.11 Filter the solvent layer into a 100 ml volumetric flask through a funnel containing solvent-moistened filter paper. An emulsion present in the extract may be broken by adding a gram of sodium sulfate into the filter paper cone.

4.12 Repeat steps 4.8-4.10 twice more, with additional portions of fresh solvent, combining all extracts in the volumetric flask.

4.13 Rinse the tip of the separatory funnel, filter paper and funnel with 10-20 ml Freon TF and collect the rinsings in the volumetric flask.

4.14 Dilute the combined extracts and washings in the volumetric flask to 100 ml.

4.15 Collect this extract in a 125 ml glass bottle, label and use for subsequent analysis onboard as well as ashore.

4.16 Dilute 10 ml of this extract to 100 ml using Freon TF.

4.17 Inject 10 ml of this Freon extract into analyzer.

4.18 Open extractor and discharge controls and discard effluent.

4.19 Refill analyzer with a fresh 20 ml aliquot of extract, open extractor and measure oil concentration.

4.20 Discharge sample and repeat step 4.16. Successive readings of each sample should agree within 5 ppm.

4.21 Retain remaining Freon extract in appropriately labeled glass bottle and seal.

4.22 If reading goes off scale (100 ppm), pipet 10.0 ml of extract into a 50 ml volumetric flask and dilute with Freon TF.

4.23 Determine oil concentration in diluted Freon extract as outlined in steps 4.18-4.22.

4.24 Proceed with steps 4.7-4.23 for each aliquot which was collected at a different time interval.

4.25 If the before and after 1.0 liter samples vary by more than 20%, the sample series will be scrapped and a new set of samples will be taken.

4.26 Run an IR/silica gel on the 0, 5 and 120 minute samples.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculation

6.1 Oil-in-water concentration with no dilution:

$$\text{ppm oil} = \text{ppm} \times \frac{E}{S}$$

Where: ppm = instrument reading

E = volume of Freon extract (ml)

S = volume of sample (ml)

6.2 Oil-in-water concentration with dilution

$$\text{ppm oil} = \text{ppm} \times D \times \frac{E}{S}$$

Where: $D = \frac{\text{total volume of dilution (ml)}}{\text{volume of extract diluted (ml)}}$

TYPING GUIDE SHEET

6.3 Plot the resulting concentration values against settling time. Comparison of the resulting curve with similar curves from other water sources will show the relative settleability of the oil in each of the water sources.

6.4 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

6.5 For final data report, convert oil measurement from ppm to mg/l by the formula:

oil (mg/l) = oil (ppm) x F

Where: F = correction factor, specific gravity of platform specific oil used for Horiba calibration, at 25°C.

7.0 Quality Control

7.1 Calibration must be performed at least once a day.

7.2 Successive readings of each sample should agree within 5 ppm. The average of the last two readings will be reported.

7.3 Repeat calibration procedure if a different container of Freon TF is used.

STANDARD OILFIELD IONIC ANALYSIS (ONSHORE)

1.0 References

1.1 American Petroleum Institute, 1968, "API Recommended Practice for Analysis of Oil-Field Water," American Petroleum Institute, Division of Production, 300 Corrigan Tower Bldg., Dallas, Texas 75201.

1.2 American Public Health Association, 1976, "Standard Methods for the Examination of Water and Wastewater," 14th Edition, American Public Health Association, 1015 Eighteenth Street NW, Washington, D.C. 20036.

1.3 Environmental Protection Agency, 1979, "Methods for Chemical Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Environmental Research Center, Cincinnati, Ohio 45268.

2.0 Equipment and Reagents

2.1 Bottles, polyethylene, 1-liter.

2.2 Nitric acid, concentrated.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

2.3 Zinc acetate.

2.4 Syringe, 10 ml.

2.5 Bottles, glass, 1-liter.

3.0 Calibration

3.1 Calibration procedures are specific for each method using the procedures listed in Table 225.

4.0 Field Procedure

4.1 Purge sample port prior to filling sample bottles.

4.2 The samples will be collected, split into aliquots and preserved according to the following schedule:

Type of Analysis	Sample Volume	Preservative
Metals	1 liter	HNO_3; pH 2
Cl, SO_4 TDS and alkalinity	1 liter	Cool, 4°C
Sulfide	1 liter	Zinc Acetate

4.3 Seal, label, inventory and pack samples for shipment.

5.0 Laboratory Procedure

5.1 The methods to be used for the analysis of each major constituent in oil-field water are listed in Table 225.

6.0 Calculations

6.1 Calculations are specific for each method using the procedures listed in the appropriate references cited in Table 225.

6.2 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Quality control aspects are specific for each method using the procedures listed in the appropriate references cited in Table 225.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE 225. METHODS FOR THE ANALYSIS OF MAJOR CONSTITUENTS IN OIL-FIELD WATERS

Constituent	Method	Reference
Sodium (Na)	Atomic absorption	EPA, pg. 273.1(1)
Potassium (K)	Atomic absorption	EPA, pg. 258.1
Calcium (Ca)	Atomic absorption	EPA, pg. 215.1
Magnesium (Mg)	Atomic absorption	EPA, pg. 242.1
Barium (Ba)	Atomic absorption	EPA, pg. 208.2
Chloride (Cl)	Automated Ferricyanide	SM, pg, 613(2)
Sulfate (SO_4)	Automated Methylthymol	SM, pg. 628
Alkalinity: Carbonate Bicarbonate	Electrometric-titration	API, pg. 8(3)
Total Dissolved Solids	Calculation	API, pg. 21
Total Dissolved Solids	Gravimetric	EPA, pg. 160.2
Iron, Fe (Total)	Atomic Absorption	EPA, pg. 236.2
Sulfide (as H_2S)	Iodometric Titration	SM, pg. 499

---

(1) "Methods for Chemical Analysis of Water and Wastes, "U.S. Environmental Protection Agency, Cincinnati, Ohio, 1979.

(2) "Standard Methods for the Examination of Water and Waste Water," 14th Edition, American Public Health Association, Washington, D.C. 1976.

(3) "API Recommended Practice for Analysis for Oil-Field Waters," American Petroleum Institute, New York, N.Y., 1968.

EPA-287 (Cin.)
(4-76)

SULFATE-REDUCING BACTERIA (OFFSHORE AND ONSHORE)

1.0 Reference

1.1 American Petroleum Institute, 1975, "API Recommended Practice for Biological Analysis of Subsurface Injection Water", American Petroleum Institute, Production Department, 300 Corrigan Tower Building, Dallas, Texas 75206.

Note: The technique for determination of sulfate-reducing bacteria follows the "API Recommended Practice for Biological Analysis of Subsurface Injection Waters (API RP 38)" for the alternative technique for estimating sulfate-reducing bacteria exactly as given in reference 1.1.

2.0 Equipment and Reagents

2.1 Thermometer, dial type, 0-100°C

2.2 Sulfate-reducing broth with acid-etched iron nail in 10 ml serum bottles, sterile.

2.3 Syringes, 1 ml, disposable, sterile.

2.4 Portable incubator.

3.0 Calibration

3.1 Not applicable.

4.0 Field Procedure

4.1 A clean sterile bottle will be used.

4.2 The tap should be allowed to flow at least 3 minutes at the sampling rate prior to collecting the sample.

4.3 The sample should be taken in such a manner as to preclude contamination from external sources as much as possible.

4.4 The time, date, temperature, and appearance of the water should be recorded at the time of sampling, and this information should be included with the sample. If possible, the total solids, and or mineral content of the water should be included.

4.5 Transfer 1 ml of sample to a bottle containing sulfate-reducing bacteria media using the syringe.

4.6 The bottle is sealed and flowed back and forth four times to mix the inoculum.

TYPING GUIDE SHEET

4.7 Using a new syringe, aseptically transfer 1 ml from this bottle to a second bottle and mix as before.

4.8 Continue this serial transfer until a dilution of 1 to 1,000,000 is reached (6 tubes).

4.9 Incubate all tubes at a temperature within 5°C of the recorded temperature of the water at time of sampling. Samples should be labeled and inventoried.

5.0 Laboratory Procedures

5.1 All bottles should be held in incubation a minimum of 4 weeks. They should be examined on the third day and the end of each week for the appearance of sulfate-reducing bacteria, as indicated by intense black color. The data will be recorded as the highest dilution indicating growth, as compared to the lowest dilution showing no growth. The data will be reported as a range in numbers, i.e., 100-1000 sulfate-reducing bacteria per milliliter.

6.0 Calculations

6.1 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

7.0 Quality Control

7.1 Sulfate-reducing bacterial cultures will be prepared in duplicate.

7.2 The sample should be cultured as soon as possible.

7.3 The sample should be handled in such a manner as to avoid radical changes in temperature between time of sampling and time of examination of the sample.

7.4 All reasonable laboratory precautions will be taken to assure aseptic conditions of sampling equipment.

EQUILIBRATION (ONSHORE)

1.0 References

1.1 Environmental Protection Agency, 1979, "Methods for Chemical Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Environmental Research Center, Cincinnati, Ohio 45268.

1.2 Operation Instructions, Model OCMA-200 Oil Content Analyzer, Horiba Instruments Incorporated, Houston, Texas 77092.

EPA-287 (Cin.)
(4-76)

2.0 Equipment and Reagents

2.1 Flask, Erlenmeyer, 1000 ml.

2.2 Separatory funnel, graduated, 125 ml.

2.3 Oil-in-water analyzer, Horiba OCMA-200.

2.4 Graduated cylinder, stoppered, 100 ml.

2.5 Syringe, glass, 10 µl, 10 ml.

2.6 Freon TF (1,1,2 - trichloro - 1,2,2 - trifluoroethane).

2.7 Brine solution equivalent for particular oil field, as determined by the ionic analysis.

2.8 Constant temperature bath.

2.9 Hydrochloric acid, 6N.

3.0 Calibration

3.1 Inject 10 ml of Freon TF into extraction chamber.

3.2 Turn extractor control to the open position.

3.3 Adjust zero control.

3.4 Prepare 100 ppm standard by injecting 10 microliters of oil into a 100 ml volumetric flask and dilute with Freon.

3.5 Inject 10 ml of 100 ppm standard into extraction chamber.

3.6 Open extraction cell and discharge sample.

3.7 Close extraction cell and refill with 10 ml of standard.

3.8 Adjust span for 100 ppm oil.

4.0 Field Procedure

4.1 Purge sample point.

4.2 Fill each sample bottle. Seal, label, inventory and pack for shipment.

4.3 Two samples will be taken for duplicate analysis.

5.0 Laboratory Procedure

5.1 Add a long piece of clean glass tubing to a 4000 ml Erlenmeyer flask. The tubing should be resting on the bottom of the container and extend several inches above the mouth. Tape the tubing to the mouth of the flask so that it cannot move side to side.

5.2 Carefully pour 600 ml of brine solution into one flask without splashing the solution onto the interior surfaces.

5.3 Dispense 2400 ml of the test crude oil from a separatory funnel by allowing the oil to slowly flow down the outside of the glass tubing. The oil flow should be slow enough that no deflection of the brine interface occurs. This will yield an oil to water ratio of 4 to 1. The second flask will use the oil to water ratio found in the production system on the platform (formation ratio).

5.4 Seal the mouth of the flask and protruding end of the tubing with aluminum foil.

5.5 Place the container in a constant temperature bath at 180°F (82°C).

5.6 Allow the sample to equilibrate at temperature undisturbed for 14 days.

5.7 Remove a small sample of water by siphoning water up the glass tubing.

5.8 Rinse a clean 125 ml, graduated separatory funnel with three successive 10 ml portions of Freon TF and drain.

5.9 Add 30 ml Freon TF and 1.5 ml 6N HCl.

5.10 Collect 50.0 ml of equilibrated brine sample, stopper and shake.

5.11 Read the total volume of liquid and calculate the sample volume.

5.12 Shake vigorously for 1 minute and allow to separate for 5 minutes.

5.13 Collect lower Freon TF layer in a 100.0 ml glass volumetric flask.

5.14 Extract the sample with 30 ml Freon TF twice more and add extracts to the volumetric flask.

5.15 Dilute the extract to 100.0 ml with Freon TF.

5.16 Inject 10 ml of Freon extract into analyzer.

5.17 Open extractor and discharge controls and discard effluent.

5.18 Refill analyzer with a fresh 10 ml aliquot of extract, open extractor and measure oil concentration.

5.19 Discharge sample and repeat step 5.18. Successive readings of each sample should agree within 5 ppm.

5.20 Retain remaining Freon extract in appropriately labeled glass bottle and seal.

5.21 If reading goes off scale (100 ppm), pipet 10.0 ml of extract into a 50 ml volumetric flask and dilute with Freon TF.

5.22 Determine oil concentration in diluted Freon extract as outlined in steps 5.16 - 5.19.

5.23 An IR-Oil w/silica gel test and a filtered brine test will be run on each equilibrated brine. Methods for these tests appear elsewhere in this document.

6.0 Calculation

6.1 Oil-in-water concentration at equilibrium with no dilution:

$$\text{ppm oil} = \text{ppm} \times \frac{E}{S}$$

Where: ppm = instrument reading

E = volume of Freon extract (ml)

S = volume of sample (ml)

6.2 Oil-in-water concentration at equilibrium with dilution:

$$\text{ppm oil} = \text{ppm} \times D \times \frac{E}{S}$$

Where: $D = \frac{\text{total volume of dilution (ml)}}{\text{volume of extract diluted (ml)}}$

6.3 Record data in laboratory notebook. At end of each day transfer data from notebook to data sheets, referring data sheet back to actual notebook number and page under the "page ____ of ____" section on the data sheet.

6.4 For final data report, convert oil measurement from ppm to mg/l by the formula:

$$\text{oil (mg/l)} = \text{oil (ppm)} \times F$$

Where: F = correction factor, specific gravity of platform specific oil used for Horiba calibration, at 25°C.

7.0 Quality Control

7.1 Calibration of the IR analyzer must be performed at least once a day.

7.2 Successive readings of each sample should agree within 5 ppm. The average of the last two readings will be reported.

7.3 Repeat calibration procedure if a different container of Freon TF is used.

FILTERED BRINE (OFFSHORE)

1.0 Reference

1.1 This procedure follows the sample collection procedures commonly employed by those oil companies using the method, and have shown good results and are preferred. (Carl Dimon, Mobil Oil, personal communication, 1979).

2.0 Equipment and Reagents

2.1 Filter paper, Whatman No. 40, 24 cm.

2.2 Glass funnel with internal ribs and short stem, 100 mm diameter, 100 mm stem.

2.3 Graduated cylinder, stoppered, 100 ml.

2.4 Separatory funnel, graduated, 125 ml.

2.5 Oil-in-water analyzer, Horiba OCMA-200.

2.6 Syringes, glass 10 μl.

2.7 Freon TF (1,1,2 - trichloro - 1,2,2 - trifluoroethane).

2.8 Crude oil.

2.9 Volumetric flask 100 ml, 50 ml.

2.10 Hydrochloric acid, 6N.

2.11 Dispenser, glass, 50 ml.

2.12 Bottle, glass, 125 ml.

2.13 Deionized water.

3.0 Calibration

3.1 Inject 10 ml of Freon TF into extraction chamber.

3.2 Turn extractor control to the open position.

3.3 Adjust zero control.

3.4 Prepare 100 ppm standard by injecting 10 microliters of oil into a 100 ml volumetric flask and dilute with Freon.

3.5 Inject 10 ml of 100 ppm standard into extraction chamber.

3.6 Open extraction cell and discharge sample.

3.7 Close extraction cell and refill with 10 ml of standard.

3.8 Adjust span for 100 ppm oil.

4.0 Field Procedure

4.1 Wet filter with deionized water.

4.2 Put funnel stem into graduated cylinder.

4.3 Purge sample flow line.

4.4 Put funnel under sample cock and fill the funnel with brine.

(Note: The funnel holds about 100 cc.)

4.5 Filter long enough to collect 25 to 50 ml of filtrate. There is no need to wait for all the sample to filter.

4.6 Remove the funnel, replace the cap; sample is ready for analysis.

4.7 Rinse a clean 125 ml, graduated separatory funnel with three successive 10 ml portions of Freon TF and drain.

4.8 Add 50.0 ml Freon TF and 1.5 ml 6N HCl.

4.9 Collect 50 ml of aqueous sample, stopper and shake.

4.10 Read the total volume of liquid and calculate the sample volume.

4.11 Shake vigorously for 1 minute and allow to separate for 5 minutes.

4.12 Collect lower Freon TF layer in a glass beaker.

4.13 Inject 10 ml of Freon extract into analyzer.

4.14 Open extractor and discharge controls and discard effluent.

4.15 Refill analyzer with a fresh 10 ml aliquot of extract, open extractor and measure oil concentration.

4.16 Discharge sample and repeat step 4.15. Successive readings of each sample should agree within 5 ppm.

4.17 Retain remaining Freon extract for additional analysis in

TYPING GUIDE SHEET

appropriately labeled glass bottle and seal.

4.18 If reading goes off scale (100 ppm), pipet 10.0 ml of extract into a 50 ml volumetric flask and dilute with Freon TF.

4.19 Determine oil concentration in diluted Freon extract as outlined in steps 4.13-4.16.

5.0 Laboratory Procedure

5.1 Not applicable.

6.0 Calculation

6.1 Oil-in-water concentration with no dilution:

$$\text{ppm oil} = \text{ppm} \times \frac{E}{S}$$

Where: ppm = instrument reading

E = volume of Freon extract (ml)

S = volume of sample (ml)

6.2 Oil-in-water concentration with dilution:

$$\text{ppm oil} = \text{ppm} \times D \times \frac{E}{S}$$

Where: $D = \dfrac{\text{total volume of dilution (ml)}}{\text{volume of Freon extract diluted (ml)}}$

6.3 For final data report, convert oil measurement from ppm to mg/l by the formula:

$$\text{Oil (mg/l)} = \text{oil (ppm)} \times F$$

Where: F = correction factor, specific gravity of platform specific oil used for Horiba calibration at 25°C.

7.0 Quality Control

7.1 Calibration must be performed at least once a day.

7.2 Successive readings of each sample should agree within 5 ppm. The average of the last two readings will be reported.

7.3 Repeat calibration procedure if a different container of Freon TF is used.

EPA-287 (Cin.)
(4-78)

IR SCAN OF FREON EXTRACTS (ONSHORE)

1.0 Reference

1.1 Environmental Protection Agency, 1976, "Methods for Chemical Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Environmental Research Center, Cincinnati, Ohio 45268.

2.0 Equipment and Reagents

2.1 IR spectrophotometer (Perkin-Elmer Model 621).

2.2 Bottles, glass.

3.0 Calibration

3.1 Not applicable.

4.0 Field Procedure

4.1 All remaining Freon extracts from field IR analyses will be appropriately labeled, sealed, inventoried and packed for shipment.

5.0 Laboratory Procedure

5.1 If preliminary field data indicate the true concentration of oil in the Freon extract is only a few ppm, then the resulting IR scans may not be definitive. If this is the case, all effluent IR extracts from a given platform will be combined. The combined extracts will be evaporated to a small volume using a Kuderna-Danish concentrator and an IR scan on the residue will be run. In addition, all solvent may have to be removed to obtain a sufficient scan.

5.2 Run IR spectra (4000-650cm^{-1}) on samples from oil fields showing highly soluble components.

6.0 Calculations

6.1 Not applicable.

7.0 Quality Control

7.1 Crude oils contain hydrocarbon bonds with a strong absorption band in the 2930 cm^{-1} region. Caution must be exercised in the selection of the 2930 cm^{-1} peak, as it may not always be the largest peak in that region. Several scans may be needed to provide sufficient detail allowing some peaks to go off scale.

APPENDIX B

QUALITY ASSURANCE/QUALITY CONTROL PLAN

QUALITY ASSURANCE/QUALITY CONTROL ANALYTICAL METHODOLOGY

Oil and Grease IR

All glassware used in the collection, extraction and analysis of samples for oil and grease concentrations by infrared analysis was cleaned prior to processing of each sample. The glassware was washed and brushed with soapy tap water, rinsed with tap water and then with deionized water several times, and finally rinsed with three portions of Freon TF. Particularly oily glassware was rinsed with methyl ethyl ketone before washing with tap water. Acetone rinses were avoided at all times due to the limited solubility of acetone in Freon TF. Once clean, the glassware was sealed and set aside until needed. Immediately before use, all glassware was again rinsed with a small portion of Freon TF. The Freon rinse was drained directly into the Horiba IR analyzer and the concentration of hydrocarbons was measured. If a significant reading (>5 ppm) was obtained, the glassware was again rinsed with Freon until acceptable readings were obtained. Once a reading of <5 ppm was obtained, the glassware was immediately put to use.

Instrument responses over the range of 0 to 100 ppm were verified as linear for each Horiba OCMA-200 used in Phase I. All three IR analyzers were found to be statistically linear within that working range (Table 226). In all cases percent agreement ranged from 98 - 105%. Least squares linear regression analyses yielded significant correlation between standard values and analyzer readings for all three units. Calibration of the instrument in the field was performed prior to daily analysis and checked at the end of each day.

Once the IR analyses were completed, the remaining sample was retained for subsequent laboratory processing. Samples were reanalyzed after return to the TI Dallas Laboratories to verify preliminary field data. All Phase I field readings were verified correct by reanalysis before the data were reported to C-E Crest. Selected Phase II results were rechecked.

During field analysis, when a new container of Freon TF was opened for use, the IR analyzer was recalibrated using the new Freon sample and a sample of the Freon was collected and analyzed for contamination using the previous Freon as a standard reference.

TABLE 226. RESULTS OF LINEARITY TEST FOR HORIBA OCMA-200

Unit number	Standard concentration	Analyzer readings (ppm) Trial 1	Analyzer readings (ppm) Trial 2	Analyzer readings (ppm) Trial 3	Mean value	% Agreement
1	0	0	0	0	0	100
	20	21	21	21	21	105
	40	39	40	40	39.7	99
	60	60	60	60	60	100
	80	82	82	82	82	102
	100	100	100	100	100	100
2	0	0	0	0	0	100
	20	21	21	21	21	105
	40	38	39	39	38.7	99
	60	59	59	59	59	98
	80	80	80	80	80	100
	100	100	100	100	100	100
3	0	0	0	0	0	100
	20	21	21	21	21	105
	40	40	40	40	40	100
	60	60	60	60	60	100
	80	82	82	82	82	102
	100	100	100	100	100	100

Oil and Grease - Gravimetric

All glassware used in the collection, extraction and analysis of samples for oil and grease concentrations by gravimetric procedures was treated in the same manner as was used for oil and grease by infrared analysis.

Blank determinations were made using the same batch of Freon TF used in the field extractions. Each time a new batch of Freon TF was used, a Freon blank was collected for later analysis. Each gravimetric sample was corrected for solvent by processing blanks.

Temperature

Water samples were taken from the effluent stream after the sample port had been purged for several minutes. The water was collected in a 500-ml plastic beaker and shielded from winds while the temperature reading was made. The normal time span between sample collection and temperature reading was 2-3 minutes. Given the heat capacity of the brine solution, little heat loss could be expected in this short time interval. It is expected that the system temperature data adequately represent actual system temperatures.

pH

The pH data were collected with a battery operated pH meter using a combination electrode. The system was calibrated with a pH 6.86 standard buffer immediately prior to use. The response of the combination electrode over the pH range 4.01 - 9.18 was tested every other day using three standard buffers. If the response did not agree with the Nernst slope response within 95%, the electrode was replaced and the process was repeated. Temperature and pH data were taken at the same time.

Boiling Range Distribution

A Perkin-Elmer Sigma 2 gas chromatograph equipped with a flame ionization detector was used in the determination of crude oil boiling range distribution. Data were collected with a Perkin-Elmer Sigma 10 chromotography data station. All quality control criteria as established in ANSI/ASTM Standard Test Method D22887-73 were followed. Samples were analyzed several times to produce a chart output which was used to aid in the interpretation of the crude oil equilibration test results.

Specific Gravity, Oil and Water

The hydrometers used in the measurement of both crude oil and brine specific gravities were ASTM recommended design. The hydrometers in the 0.800 - 0.900 and the 1.0 - 1.25 g/cm^3 range were corrected for the surface tension effect to determine actual principal surface height from the hydrometer readings by using a transparent fluid with surface tensions similar to those expected for crude oil and brine. These correction factors were applied to all field data collected. All fluid samples were allowed to reach thermal equilibrium in the hydrometer cylinders before readings were made. Temperatures at which readings were made were recorded in field notebooks.

Water Cut

API design centrifuge tubes were used with a hand powered centrifuge. Centrifuging was repeated until consecutive readings agreed within 0.2%.

Suspended Solids

All suspended solids samples were collected with Teflon in-line filter holders so that no oxidation-produced particulate material would prejudice the suspended solids data. The filters were carefully removed from the holders, placed in individual plastic petri dishes, and frozen to retard evaporative or bacterial alteration of the collected material. Separate blank filters were used to correct for field and laboratory contamination during processing. All blank filters were handled in an analogous manner to suspended solids filters except that no filtration was conducted. The suspended solids data were corrected for process contamination prior to being reported to C-E Crest.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
8 1/2"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Surface Tension

The surface tensiometers employed for testing were ASTM design and all required quality control procedures and calibration procedures were followed as specified in Standard Test Method D1590-60 (1977). Tensiometers were calibrated daily while onboard the platforms; records of calibration data were kept in field notebooks and in the tensiometer calibration log.

Silica Gel Adsorption

All glassware used in the collection, extraction and analysis of samples for silica gel-adsorbable hydrocarbons in the Freon extracts was treated in the same manner as previously detailed for oil and grease by infrared analysis. The silica gel portions were sealed in capped polypropylene vials, but this did not prevent moisture deactivation of the silica gel while offshore. Because of this deactivation problem, some silica gel adsorption tests were redone in the TI Dallas laboratories.

Crude Oil Equilibration

All glassware used in the collection, extraction and processing of samples for infrared analysis of crude oil equilibration tests was treated in the same manner as done for oil and grease concentrations by infrared analysis. Duplicate 14-day incubations were conducted, duplicate samples were drawn from the incubation flasks, IR analyses were performed and the results were averaged to produce a single oil and grease concentration value for each incubation. For each platform two crude oil equilibration values were reported.

Each of the Freon extracts was analyzed by gas chromatography to establish a finger print of the Freon-extractable material. This was then compared to the gas chromatographic analyses made for the boiling range distribution determinations done for each crude oil sample to assess the possibilities of solubilization versus dispersion/suspension of crude oil droplets in the brine solution.

Filtered Brine

All glassware used in the collection, extraction and analysis of filtered brine samples was treated in the same manner as previously detailed for the analysis of oil and grease concentrations by infrared analysis.

IR Scan of Addition Chemicals and Freon Extracts

Standard laboratory procedures were employed in the preparation of infrared scans of addition chemicals and Freon extracts. For some solutions, several scans were needed to provide sufficient detail to determine characteristic functional groups.

Viscosity

The viscometers used in Phase I analyses were ASTM type and were calibrated by the manufacturer. Duplicate flow time measurements were made; agreement within 0.2% was required for adequate reporting requirements. The mean value of the two measurements was reported.

Susceptibility to Oil Separation

All glassware used in this determination was treated in the same manner as previously detailed for the analysis of oil and grease concentrations by infrared analysis. Replicate tests were made on each platform; duplicate tests were not made. The time interval between replicate testing was several days.

Standard Oilfield Ionic Analysis

Quality control procedures specified by EPA, APHA, and API in the applicable references for each test were followed. Individual samples were preserved for metal analyses by acidification to pH 2, samples for chloride, sulfate, TDS and alkalinity analyses were cooled to 4°C and sulfide samples were preserved with 2 ml zinc acetate solution.

Bacterial Culture: Sulfate-Reducing Bacteria

Sulfate-reducing bacterial cultures were prepared in duplicate. The samples were cultured at ± 5°C from system temperature as soon as possible after collection. Radical changes in temperature were avoided between time of sampling and time of examination of the culture. Sterile equipment was used throughout; sample bottles were resterilized immediately prior to use to ensure sterile conditions at the start of samplings. Blank cultures were incubated with the platform samples to provide a check on the sample bottle integrity during incubation.

QUALITY ASSURANCE/QUALITY CONTROL CHAIN-OF-CUSTODY PROCEDURES

Prior to initial sampling (Day 01) at each platform, all sample ports were located and identified to TI personnel by the platform operator; TI personnel tagged the valves with numbered designation labels (Figure 123) so that the appropriate system ports were consistently sampled. For each platform, using TI's Analysis Program Plan, a daily sampling log was prepared detailing the hourly sampling schedule (Figure 124). An "X", placed in the appropriate row and column, designated a scheduled sample collection. Once the sample was collected, the analyst circled the "X" and initialed the entry (Figure 125). One-time samples were logged in by placing an "X" in the appropriate row and column on the checklist, circling and initialing the entry.

After the sample had been collected and properly logged, it was processed according to the field SOP written from TI's Analysis Program Plan. Data collected onboard the platform (meter readings, temperatures, volume measurements, etc.) were entered into standard TI numbered, and hardbound analytical notebooks (Figure 126). Once a page was filled, the analyst dated and signed the page as did the Field Team Supervisor to witness entries and acknowledge understanding of the page contents (Figure 127).

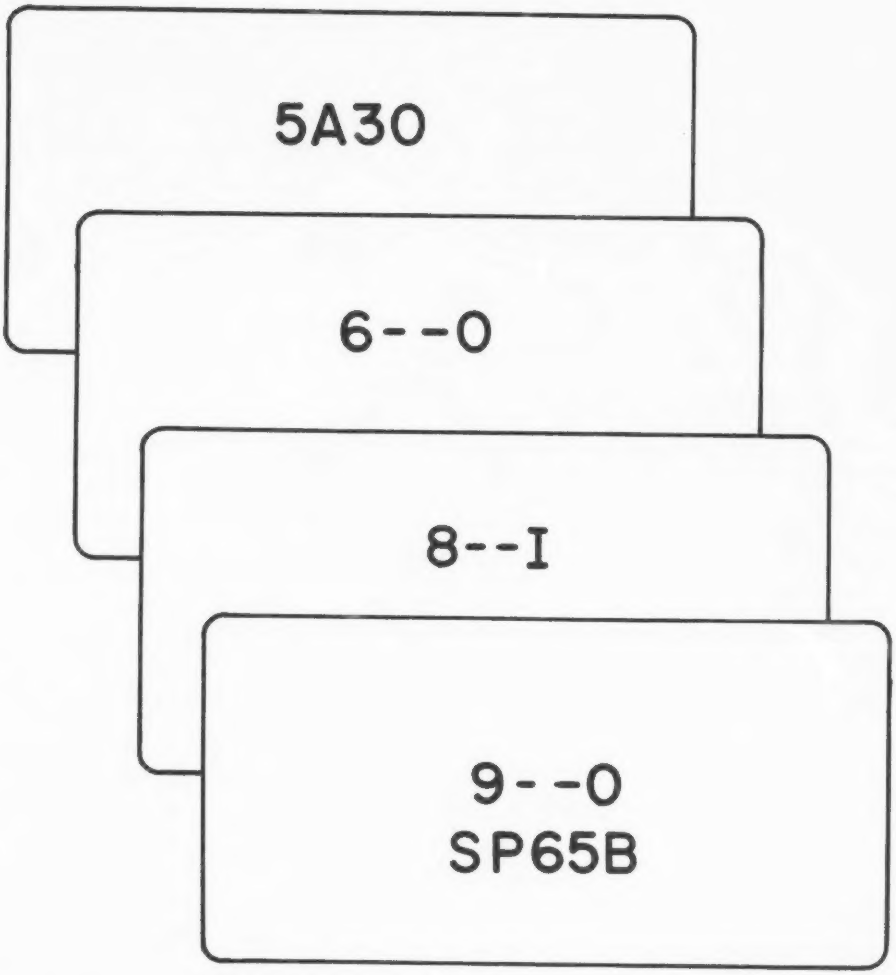

5A30
6--0
8--I
9--0
SP65B

Figure 123. Sample port designation labels.

Date:
Observer:

DAILY ANALYSIS SCHEDULE
PLATFORM SP65B

TIME	SAMPLE LOCATION		ANALYSIS PERFORMED																	
	Description	Number	IR Oil	Grav. Oil	Temp.	pH	Spec. Grav.	Water Cut	Surf. Tens.	IR Silica	IR Brine	Suscep. Separa.	Susp. Sol.	Equil.	IR Scan	Visc.	Ionic Anal.	Bact. Cult.	Part. Dist.	Boil. R/Dist.
0800	C/O/W Separator,IN	(5A31)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5A30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Desander,OUT	(15--0)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil Treater,OUT	(6--0)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Tank,IN	(8--1)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Pile,OUT	(13--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	X	-	X	X	X	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-
1000	C/O/W Separator,IN	(5A31)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5A30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Desander,OUT	(15--0)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil Treater,OUT	(6--0)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Tank,IN	(8--1)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Pile,OUT	(13--0)	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1300	C/O/W Separator,IN	(5A31)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5A30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Desander,OUT	(15--0)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil Treater,OUT	(6--0)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Tank,IN	(8--1)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Pile,OUT	(13--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1500																				

Date:
Observer:

DAILY ANALYSIS CHECKLIST
PLATFORM [illegible]

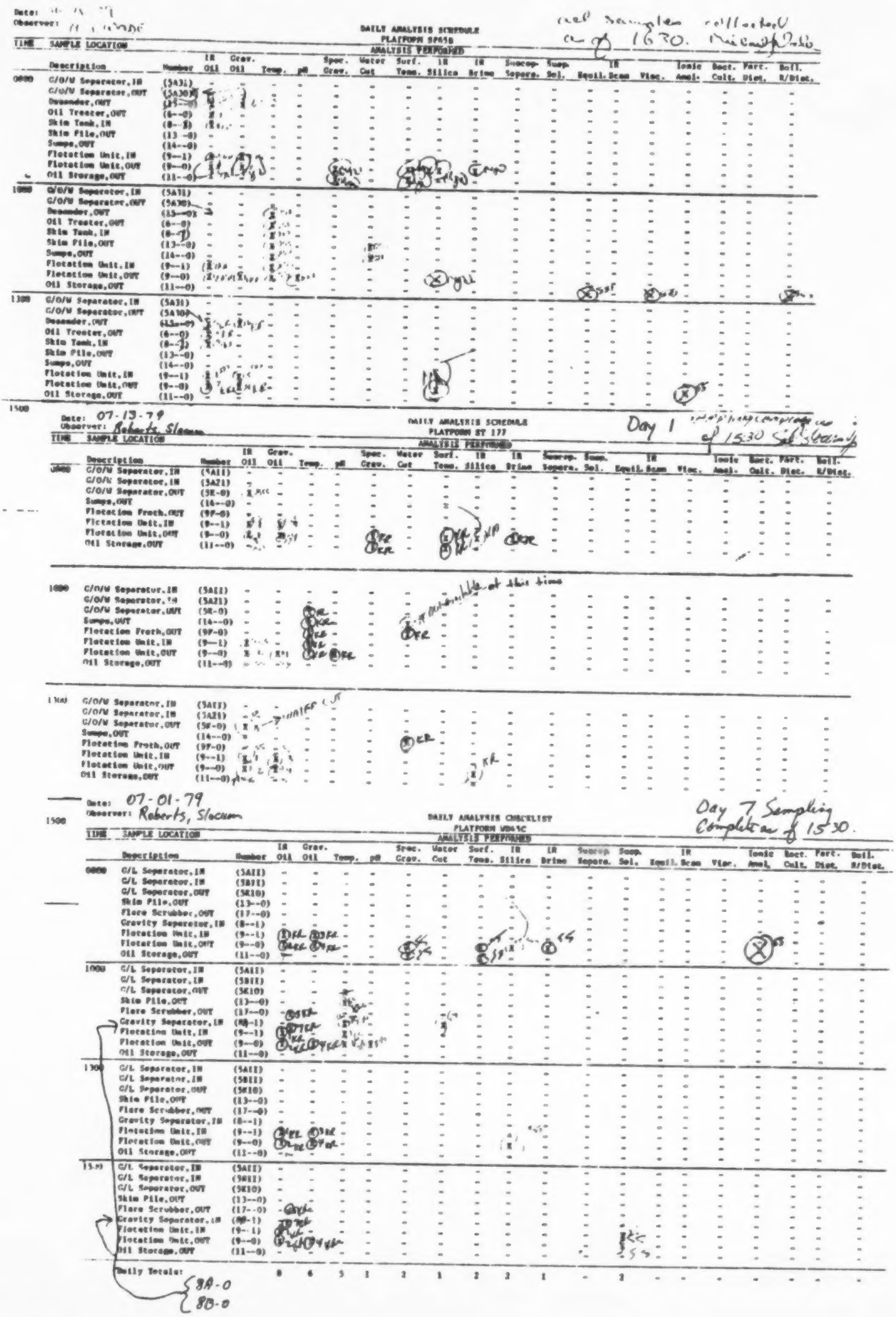
TIME	SAMPLE LOCATION		ANALYSIS PERFORMED																	
	Description	Number	IR Oil	Grav. Oil	Temp.	pH	Spec. Grav.	Water Cut	Surf. Tens.	IR Silica	IR Brine	Suscep. Separa.	Susp. Sol.	Equil.	IR Scan	Visc.	Ionic Anal.	Bact. Cult.	Part. Dist.	Boil. R/Dist.
0800	C/L Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/L Separator,IN	(5B11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/L Separator,OUT	(5K10)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Pile,OUT	(13--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flare Scrubber,OUT	(17--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gravity Separator,IN	(8--1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	X	-	X	X	X	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-
1000	C/L Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/L Separator,IN	(5B11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/L Separator,OUT	(5K10)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Pile,OUT	(13--0)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flare Scrubber,OUT	(17--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gravity Separator,IN	(8--1)	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1300	C/L Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/L Separator,IN	(5B11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/L Separator,OUT	(5K10)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Skim Pile,OUT	(13--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flare Scrubber,OUT	(17--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gravity Separator,IN	(8--1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1500																				

Date:
Observer:

DAILY ANALYSIS SCHEDULE
PLATFORM ST 177

TIME	SAMPLE LOCATION		ANALYSIS PERFORMED																	
	Description	Number	IR Oil	Grav. Oil	Temp.	pH	Spec. Grav.	Water Cut	Surf. Tens.	IR Silica	IR Brine	Suscep. Separa.	Susp. Sol.	Equil.	IR Scan	Visc.	Ionic Anal.	Bact. Cult.	Part. Dist.	Boil. R/Dist.
0800	C/O/W Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,IN	(5A21)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5K-0)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Froth,OUT	(9F-0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	X	-	X	X	X	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-
1000	C/O/W Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,IN	(5A21)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5K-0)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Froth,OUT	(9F-0)	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1300	C/O/W Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,IN	(5A21)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5K-0)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Froth,OUT	(9F-0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1500	C/O/W Separator,IN	(5A11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,IN	(5A21)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C/O/W Separator,OUT	(5K-0)	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
	Sumps,OUT	(14--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Froth,OUT	(9F-0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flotation Unit,IN	(9--1)	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
	Flotation Unit,OUT	(9--0)	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
	Oil Storage,OUT	(11--0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Daily Totals:		10	6	5	1	2	2	2	2	1	-	3	-	-	-	-	-	-	-

Figure 124. Hourly sampling schedules.



Date: [illegible]
Observer: [illegible]

DAILY ANALYSIS SCHEDULE
PLATFORM SP65B
ANALYSIS PERFORMED

all samples collected as of 1630. [illegible]

TIME	SAMPLE LOCATION Description	Number
0800	G/O/W Separator,IN	(5A31)
	G/O/W Separator,OUT	(5A30)
	Desander,OUT	(15--0)
	Oil Treater,OUT	(6--0)
	Skim Tank,IN	(8--1)
	Skim Pile,OUT	(13 -0)
	Sumps,OUT	(14--0)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1000	G/O/W Separator,IN	(5A31)
	G/O/W Separator,OUT	(5A30)
	Desander,OUT	(15--0)
	Oil Treater,OUT	(6--0)
	Skim Tank,IN	(8--1)
	Skim Pile,OUT	(13--0)
	Sumps,OUT	(14--0)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1300	G/O/W Separator,IN	(5A31)
	G/O/W Separator,OUT	(5A30)
	Desander,OUT	(15--0)
	Oil Treater,OUT	(6--0)
	Skim Tank,IN	(8--1)
	Skim Pile,OUT	(13--0)
	Sumps,OUT	(14--0)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1500		

Date: 07-13-79
Observer: Roberts, Slocum

DAILY ANALYSIS SCHEDULE
PLATFORM ST 177
ANALYSIS PERFORMED

Day 1 [illegible] as of 15:30 [illegible]

TIME	SAMPLE LOCATION Description	Number
0800	G/O/W Separator,IN	(5A11)
	G/O/W Separator,IN	(5A21)
	G/O/W Separator,OUT	(5R-0)
	Sumps,OUT	(14--0)
	Flotation Froth,OUT	(9F-0)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1000	G/O/W Separator,IN	(5A11)
	G/O/W Separator,IN	(5A21)
	G/O/W Separator,OUT	(5R-0)
	Sumps,OUT	(14--0)
	Flotation Froth,OUT	(9F-0)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1300	G/O/W Separator,IN	(5A11)
	G/O/W Separator,IN	(5A21)
	G/O/W Separator,OUT	(5R-0)
	Sumps,OUT	(14--0)
	Flotation Froth,OUT	(9F-0)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1500		

[illegible] at this time

Date: 07-01-79
Observer: Roberts, Slocum

DAILY ANALYSIS CHECKLIST
PLATFORM WD45C
ANALYSIS PERFORMED

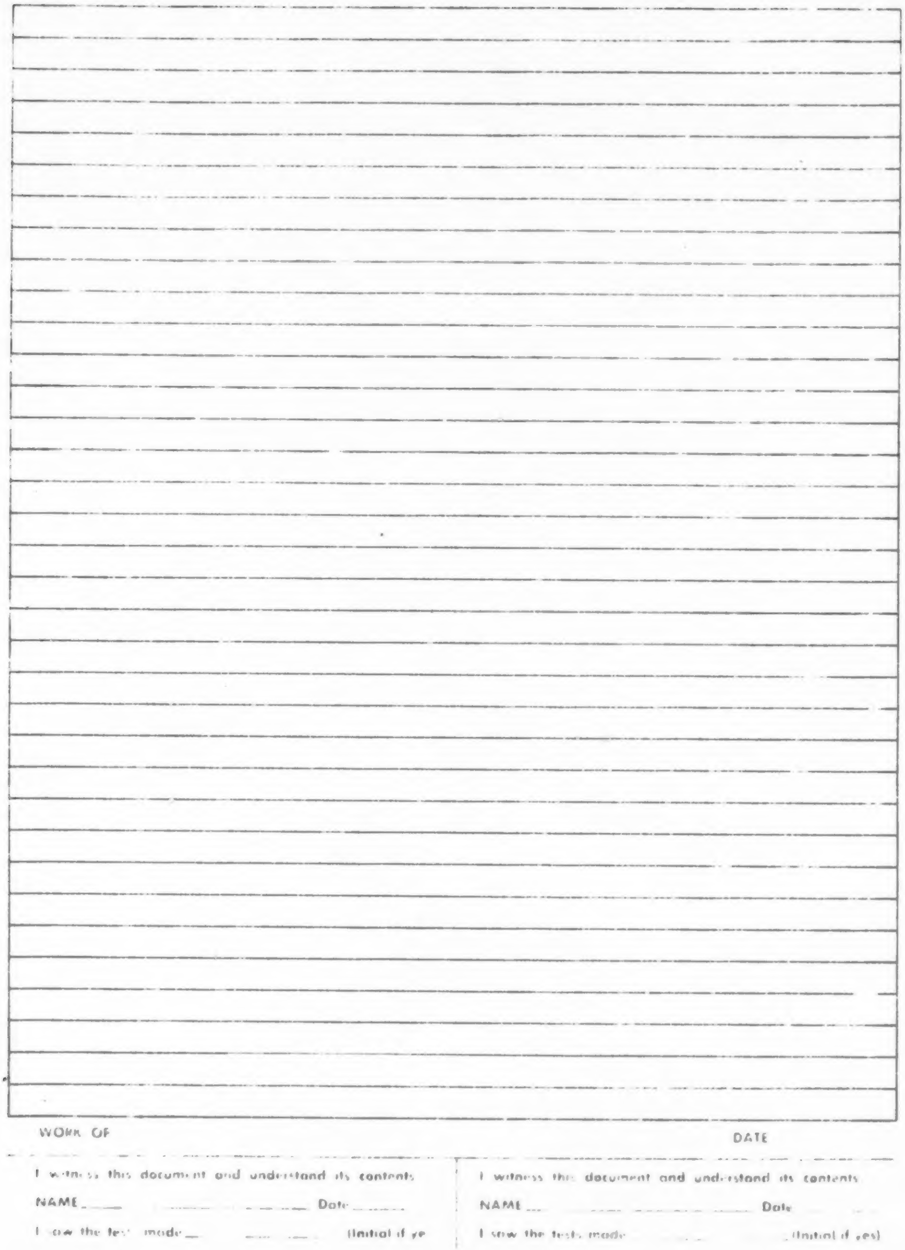
Day 7 Sampling Complete as of 1530.

TIME	SAMPLE LOCATION Description	Number
0800	G/L Separator,IN	(5A11)
	G/L Separator,IN	(5B11)
	G/L Separator,OUT	(5K10)
	Skim Pile,OUT	(13--0)
	Flare Scrubber,OUT	(17--0)
	Gravity Separator,IN	(8--1)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1000	G/L Separator,IN	(5A11)
	G/L Separator,IN	(5B11)
	G/L Separator,OUT	(5K10)
	Skim Pile,OUT	(13--0)
	Flare Scrubber,OUT	(17--0)
	Gravity Separator,IN	(8--1)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1300	G/L Separator,IN	(5A11)
	G/L Separator,IN	(5B11)
	G/L Separator,OUT	(5K10)
	Skim Pile,OUT	(13--0)
	Flare Scrubber,OUT	(17--0)
	Gravity Separator,IN	(8--1)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)
1500	G/L Separator,IN	(5A11)
	G/L Separator,IN	(5B11)
	G/L Separator,OUT	(5K10)
	Skim Pile,OUT	(13--0)
	Flare Scrubber,OUT	(17--0)
	Gravity Separator,IN	(8--1)
	Flotation Unit,IN	(9--1)
	Flotation Unit,OUT	(9--0)
	Oil Storage,OUT	(11--0)

	IR Oil	Grav. Oil	Temp.	pH	Spec. Grav.	Water Cut	Surf. Tens.	IR Silica	IR Brine	Suscep. Separa.	Susp. Sol.	Equil.	IR Scan	Visc.	Ionic Anal.	Bact. Cult.	Part. Dist.	Boil. R/Dist.
Daily Totals:	8	6	5	1	2	1	2	2	1	-	2	-	-	-	-	-	-	-

8A-0
8B-0

Figure 125. Completed hourly sampling schedules.



WORK OF

DATE

I witness this document and understand its contents

NAME ________ Date ________

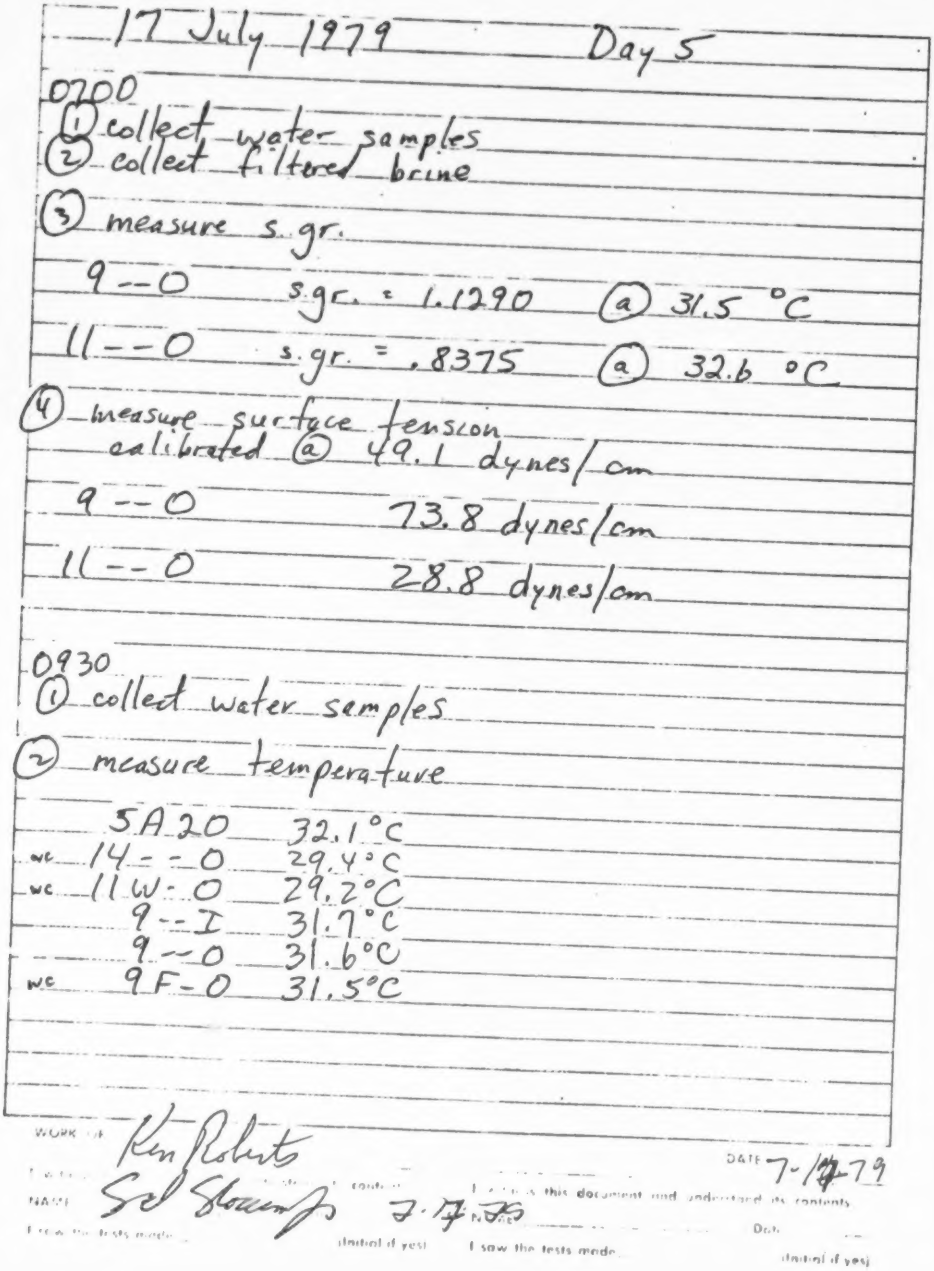
I saw the tests made ________ (Initial if ye

I witness this document and understand its contents

NAME ________ Date ________

I saw the tests made ________ (Initial if yes)

Figure 126. Example of a page from the Analytical Notebook.



17 July 1979 Day 5

0700

① collect water samples

② collect filtered brine

③ measure s.gr.

9--0 s.gr. = 1.1290 ⓐ 31.5 °C

11--0 s.gr. = .8375 ⓐ 32.6 °C

④ measure surface tension

calibrated ⓐ 49.1 dynes/cm

9--0 73.8 dynes/cm

11--0 28.8 dynes/cm

0930

① collect water samples

② measure temperature

	5A20	32.1°C
wc	14--0	29.4°C
wc	11W-0	29.2°C
	9--I	31.7°C
	9--0	31.6°C
wc	9F-0	31.5°C

WORK OF Ken Roberts

DATE 7-17-79

NAME 7·17·79

I [illegible] this document and understand its contents

I saw the tests made ___ (Initial if yes)

NAME ___ Date ___

I saw the tests made ___ (Initial if yes)

Figure 127. Example of a completed page of a notebook used in Phase I research.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Field data were extracted from the notebook and entered onto TI form 24809 Project-Specific Data Sheet (Figure 128) at the end of each platform workday. The appropriate page numbers of the notebook were entered on the data sheet; the person filling out the data sheet signed and dated the sheet; the TI Program Manager checked the entries for accuracy, and signed and dated the sheet attesting to accuracy of data transfer (Figure 129).

For field equipment requiring periodic calibration, calibration logs were maintained (Figure 130). Once the calibration or response verification was complete and recorded in the field notebook the analyst entered the appropriate data in the calibration logs. This procedure was followed for the IR analyzers, tensiometers and pH meters. The Field Team Supervisor verified all calibration log entries and signed the log at completion of each calibration.

Samples that were to be collected and then processed ashore, or samples that were processed onboard the platforms that were to be preserved for future onshore analyses, were preserved in the appropriate containers and labeled (Figure 131). Smaller labels were used on all crude oil, oil and grease, and addition chemical samples, while larger labels were used on all other samples. Table 227 lists labeling instructions provided by TI's field SOP.

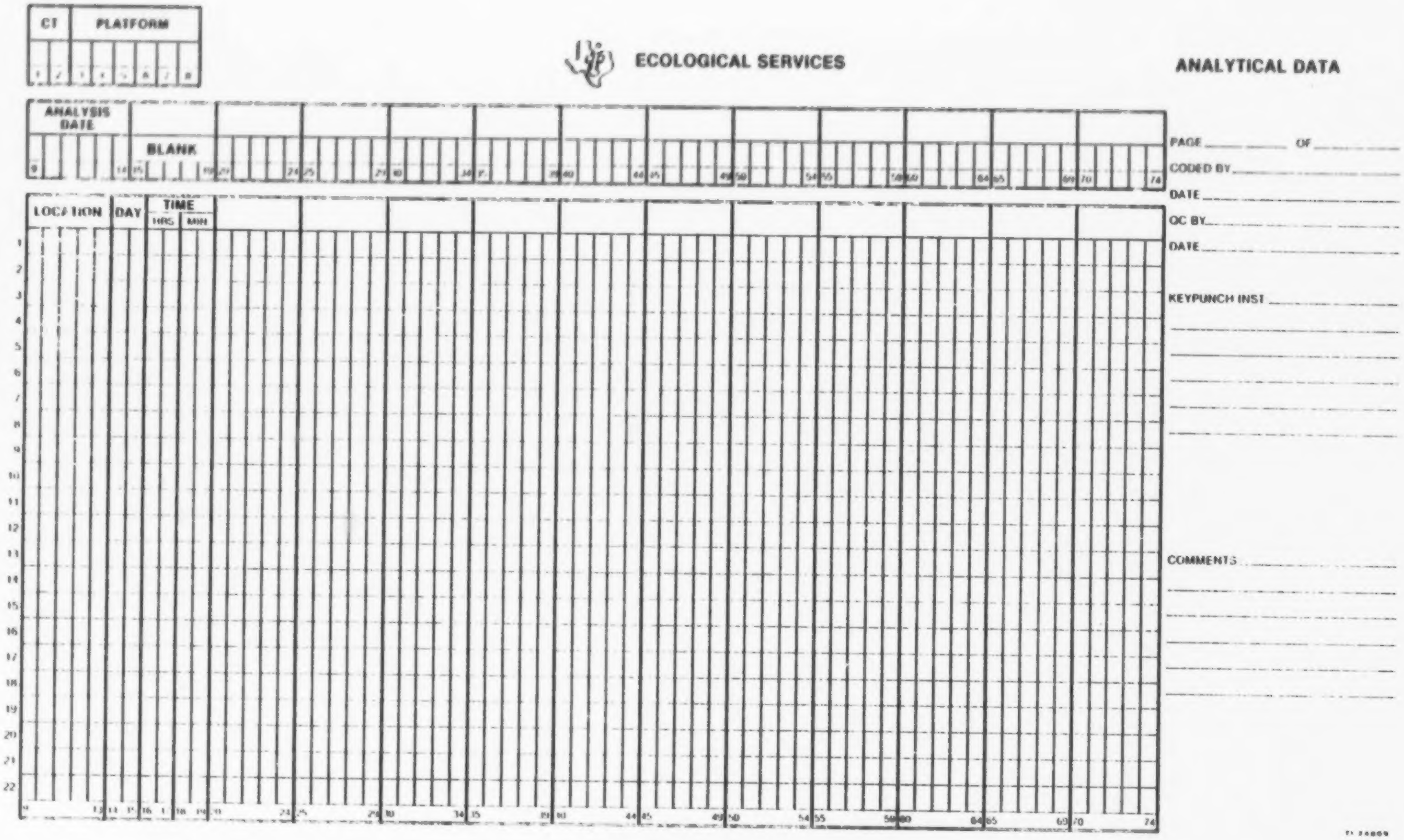
After the research was completed on each platform, all samples scheduled to be returned to TI's Dallas analytical laboratories were shipped either by automobile or via airplane. Each shipment was accompanied by a TI courier. All field and laboratory samples were placed in locked aluminum shipping containers. All samples were inventoried on TI General Ecology Sample/Data Progress Sheets, TI form 23123 (Figure 132). Inventory sheets were placed inside the shipping containers. The contents of the shipment were summarized on a General Ecology Data/Displays Progress Sheet, TI form 23120A (Figure 133), and it was carried separate from the containers. All sample logs, analytical notebooks, field data sheets, calibration logs and sample inventory sheets were received, signed for, hand-carried to Dallas by the TI courier and delivered to the TI Program Manager upon arrival in Dallas. The Program Manager signed for these materials. All written documentation was placed in locked program files as part of the permanent project documentation.

Upon receipt of the sample shipment in the Dallas analytical laboratories, the courier turned over the keys to the shipping containers to the laboratory manager who signed for receipt of the shipment. The shipping containers were opened, the contents were inventoried and checked for physical damage. The laboratory inventory was then checked against the field inventory. Accuracy in all cases was absolute. Once the inventory was verified correct, each sample bottle was assigned a laboratory processing number unique to that sample (not project-specific). All samples were processed according to a laboratory SOP prepared from TI's Analysis. Program Plan.

Laboratory data were reported to the TI Program Manager on TI form 24809 (Figure 128), the same type of data sheet utilized for reporting of the field data. Field and laboratory data were checked for transcription or

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)



CT PLATFORM

ECOLOGICAL SERVICES

ANALYTICAL DATA

ANALYSIS DATE

BLANK

LOCATION DAY TIME HRS MIN

PAGE ______ OF ______

CODED BY ______

DATE ______

QC BY ______

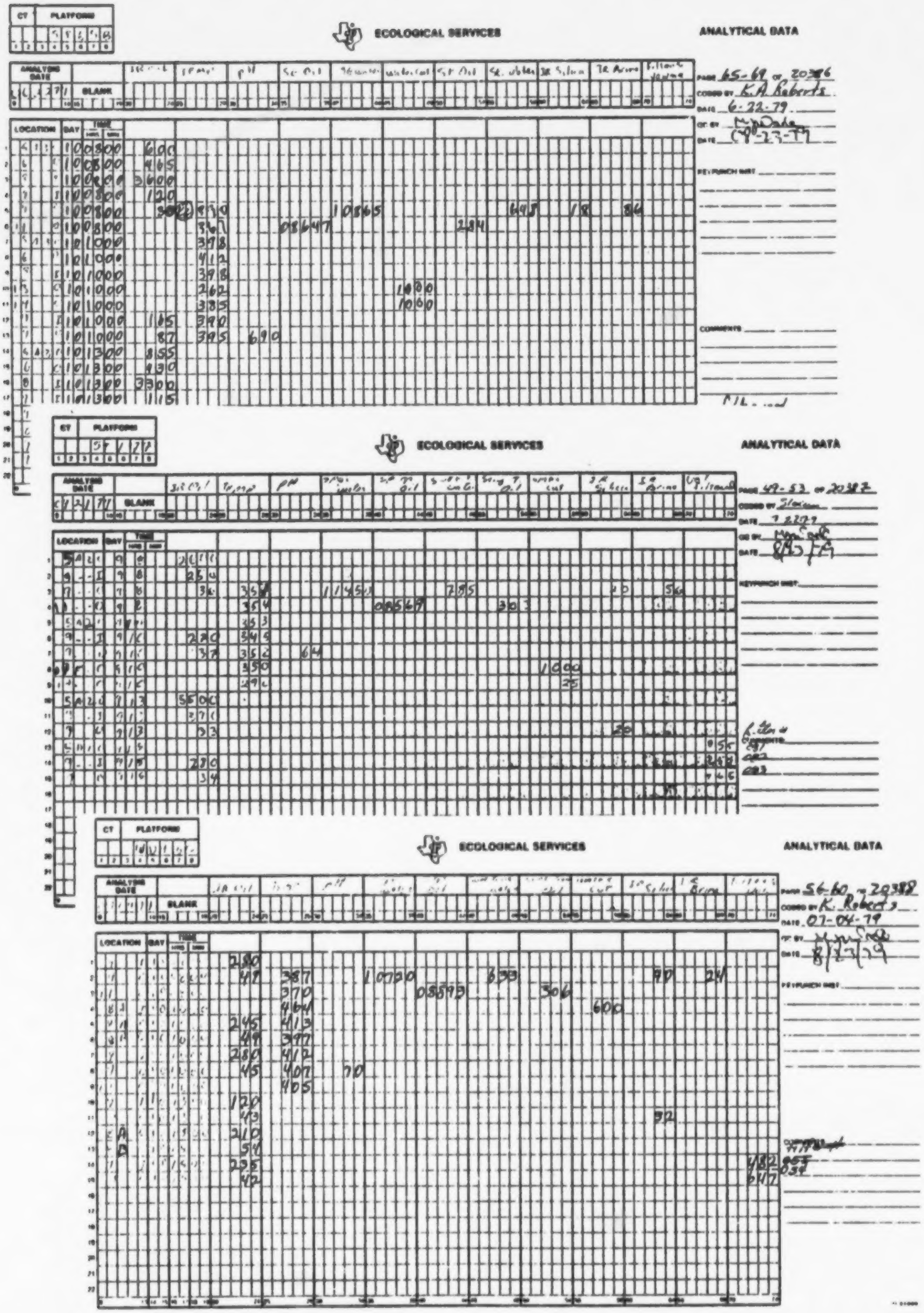
DATE ______

KEYPUNCH INST ______

COMMENTS ______

TI 24809

Figure 128. TI form 24809. Project-specific data sheet.



CT PLATFORM

ECOLOGICAL SERVICES

ANALYTICAL DATA

ANALYZING DATE BLANK

LOCATION DAY TIME

PAGE 65-69 OF 20386
CODED BY K.A. Roberts
DATE 6-22-79
QC BY
DATE [illegible]-23-79

KEYPUNCH INST.

COMMENTS

CT PLATFORM

ECOLOGICAL SERVICES

ANALYTICAL DATA

ANALYZING DATE BLANK

LOCATION DAY TIME

PAGE 49-53 OF 20387
CODED BY
DATE 7 22 79
QC BY
DATE

KEYPUNCH INST.

COMMENTS

CT PLATFORM

ECOLOGICAL SERVICES

ANALYTICAL DATA

ANALYZING DATE BLANK

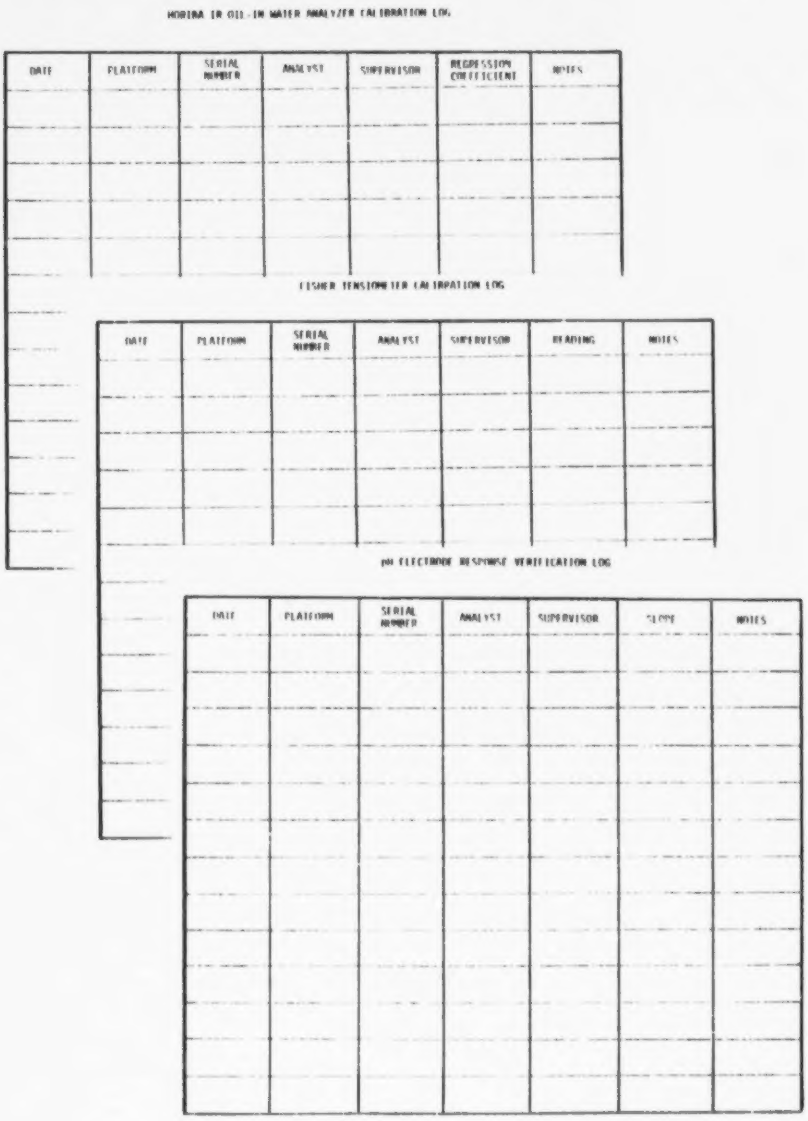
LOCATION DAY TIME

PAGE 56-60 OF 20388
CODED BY K. Roberts
DATE 07-04-79
QC BY
DATE

KEYPUNCH INST.

COMMENTS

Figure 129. Completed TI form 24809.



HORIBA IR OIL-IN WATER ANALYZER CALIBRATION LOG

DATE	PLATFORM	SERIAL NUMBER	ANALYST	SUPERVISOR	REGRESSION COEFFICIENT	NOTES

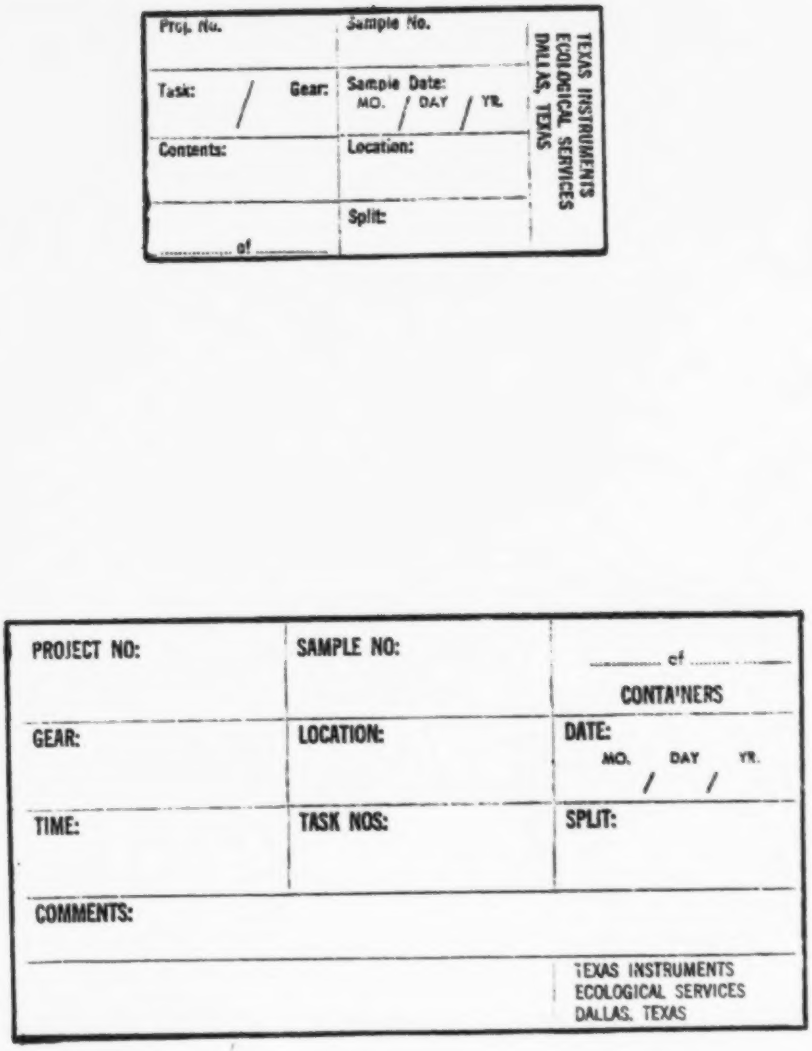
FISHER TENSIOMETER CALIBRATION LOG

DATE	PLATFORM	SERIAL NUMBER	ANALYST	SUPERVISOR	READING	NOTES

pH ELECTRODE RESPONSE VERIFICATION LOG

DATE	PLATFORM	SERIAL NUMBER	ANALYST	SUPERVISOR	SLOPE	NOTES

Figure 130. Calibration log sheets used in Phase I research.



Proj. No.	Sample No.	TEXAS INSTRUMENTS ECOLOGICAL SERVICES DALLAS, TEXAS
Task: / Gear:	Sample Date: MO. / DAY / YR.	
Contents:	Location:	
.... of	Split:	

PROJECT NO:	SAMPLE NO:	.... of .... CONTAINERS
GEAR:	LOCATION:	DATE: MO. DAY YR. / /
TIME:	TASK NOS:	SPLIT:
COMMENTS:		
		TEXAS INSTRUMENTS ECOLOGICAL SERVICES DALLAS, TEXAS

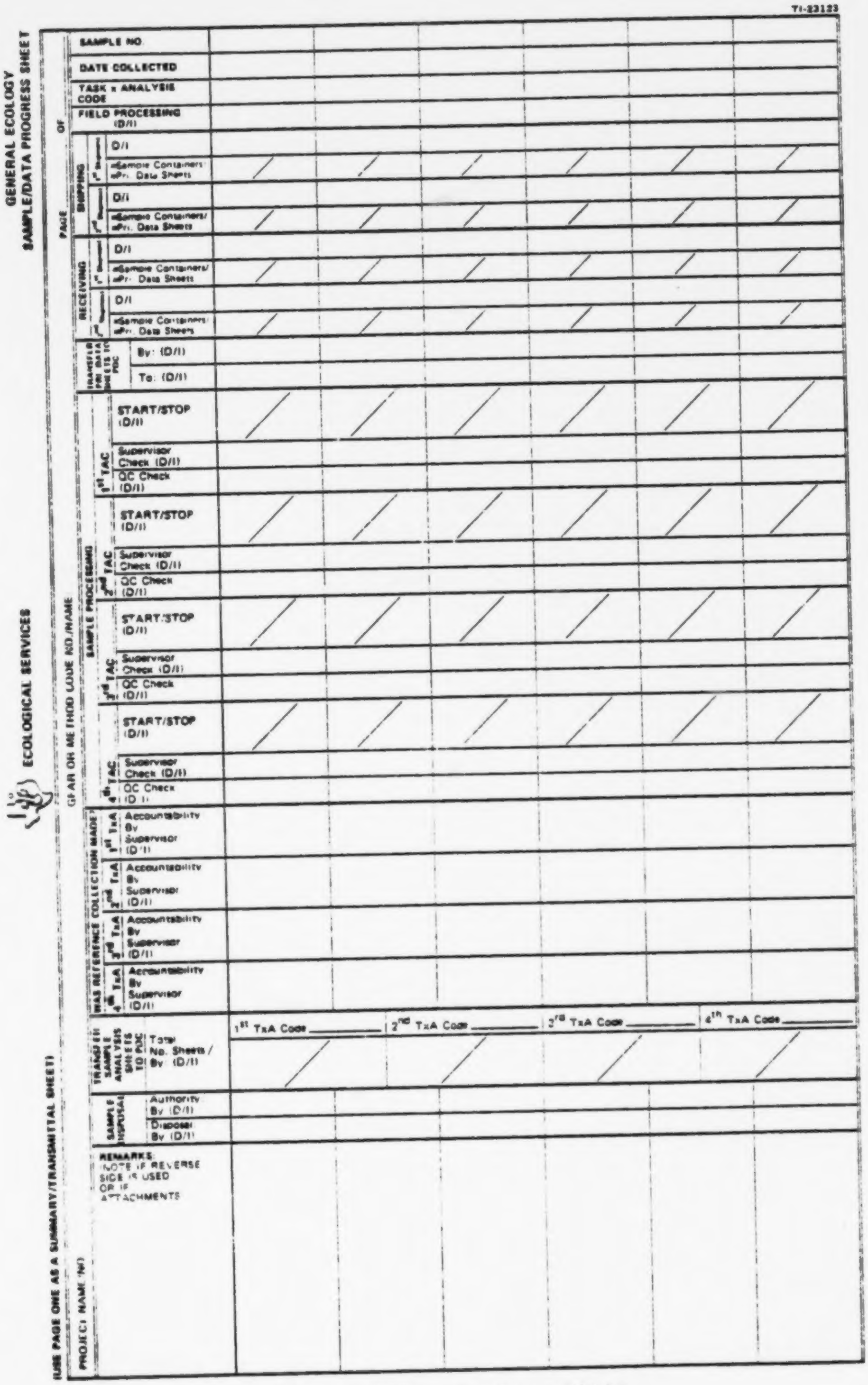
Figure 131. Standard TI sample labels.

TABLE 227. LABELING INSTRUCTIONS

Field labels shall be filled out as follows:

Proj. No.:	8931
Sample No.:	Location sample taken from (Number from sample schedule.)
Task:	Day of sampling 1-10
Gear:	Hourly sample (0800, 1000, 1300, 1500)
Sample Date:	Date Collected
Contents:	Freon Water Oil
Location:	SP65B WD45C ST177
Split:	Diluted Undiluted

____ of ____ number ____ of total ____.



TI-23123

GENERAL ECOLOGY
SAMPLE/DATA PROGRESS SHEET

PAGE ____ OF ____

ECOLOGICAL SERVICES

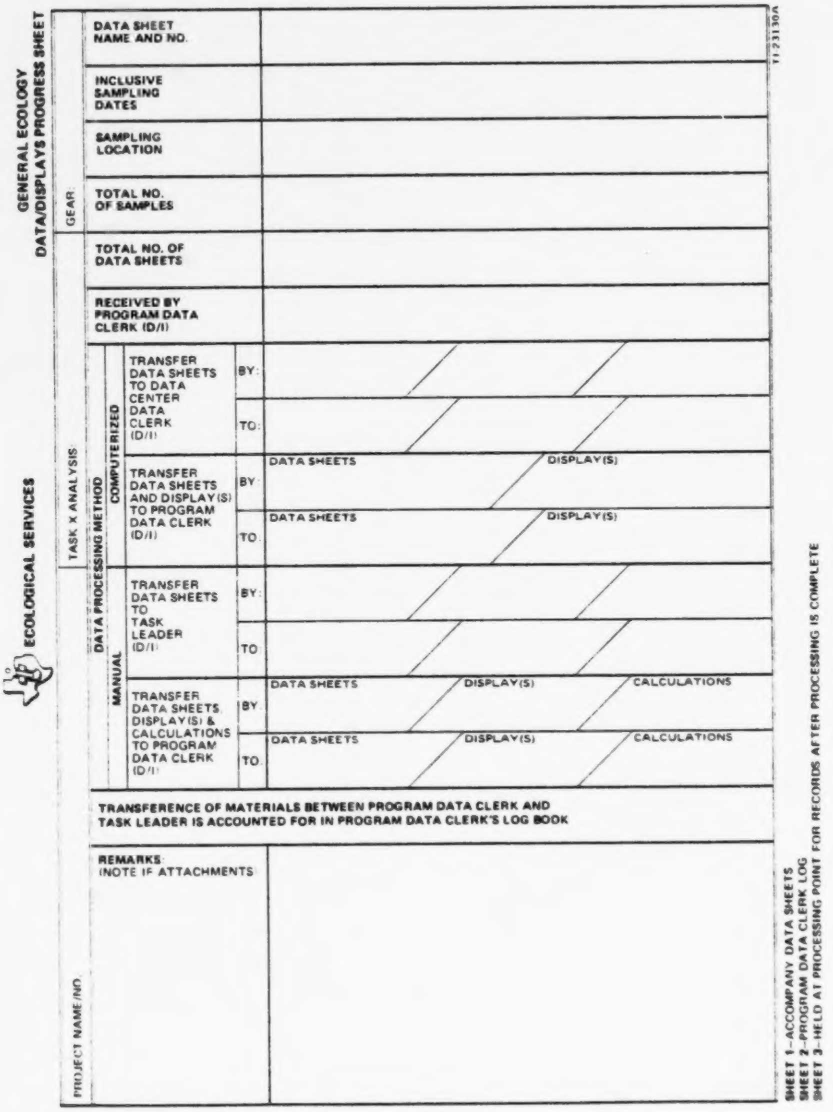
GEAR OR METHOD CODE NO./NAME

(USE PAGE ONE AS A SUMMARY/TRANSMITTAL SHEET)

PROJECT NAME (N)

SAMPLE NO.								
DATE COLLECTED								
TASK x ANALYSIS CODE								
FIELD PROCESSING (D/I)								
SHIPPING	1st	D/I						
		#Sample Containers/ #Pr. Data Sheets	/	/	/	/	/	/
	2nd	D/I						
		#Sample Containers/ #Pr. Data Sheets	/	/	/	/	/	/
RECEIVING	1st	D/I						
		#Sample Containers/ #Pr. Data Sheets	/	/	/	/	/	/
	2nd	D/I						
		#Sample Containers/ #Pr. Data Sheets	/	/	/	/	/	/
TRANSFER PRI DATA SHEETS TO PDC		By: (D/I)						
		To: (D/I)						
SAMPLE PROCESSING	1st TAC	START/STOP (D/I)	/	/	/	/	/	/
		Supervisor Check (D/I)						
		QC Check (D/I)						
	2nd TAC	START/STOP (D/I)	/	/	/	/	/	/
		Supervisor Check (D/I)						
		QC Check (D/I)						
	3rd TAC	START/STOP (D/I)	/	/	/	/	/	/
		Supervisor Check (D/I)						
		QC Check (D/I)						
	4th TAC	START/STOP (D/I)	/	/	/	/	/	/
		Supervisor Check (D/I)						
		QC Check (D/I)						
WAS REFERENCE COLLECTION MADE?	1st TxA	Accountability By Supervisor (D/I)						
	2nd TxA	Accountability By Supervisor (D/I)						
	3rd TxA	Accountability By Supervisor (D/I)						
	4th TxA	Accountability By Supervisor (D/I)						
TRANSFER SAMPLE ANALYSIS SHEETS TO PDC		Total No. Sheets / By (D/I)	1st TxA Code ______ /	2nd TxA Code ______ /	3rd TxA Code ______ /	4th TxA Code ______ /		
SAMPLE DISPOSAL		Authority By (D/I)						
		Disposal By (D/I)						
REMARKS: (NOTE IF REVERSE SIDE IS USED OR IF ATTACHMENTS								

Figure 132. TI form 23123, general ecology sample/data progress sheet.



ECOLOGICAL SERVICES

GENERAL ECOLOGY
DATA/DISPLAYS PROGRESS SHEET

PROJECT NAME/NO.:
TASK X ANALYSIS:
GEAR:

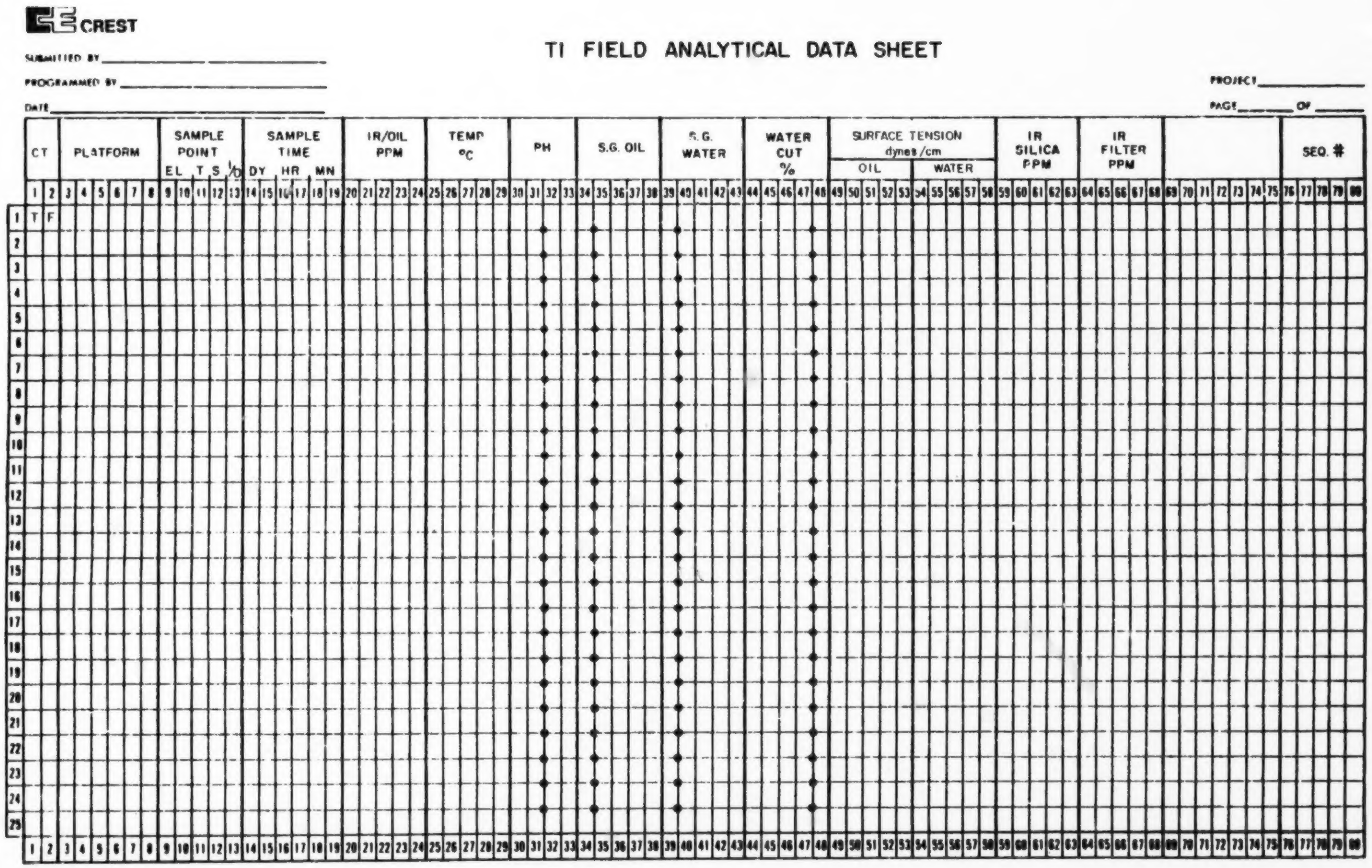
DATA SHEET NAME AND NO.						
INCLUSIVE SAMPLING DATES						
SAMPLING LOCATION						
TOTAL NO. OF SAMPLES						
TOTAL NO. OF DATA SHEETS						
RECEIVED BY PROGRAM DATA CLERK (D/I)						
DATA PROCESSING METHOD	COMPUTERIZED	TRANSFER DATA SHEETS TO DATA CENTER DATA CLERK (D/I)	BY:			
			TO:			
		TRANSFER DATA SHEETS AND DISPLAY(S) TO PROGRAM DATA CLERK (D/I)	BY:	DATA SHEETS	DISPLAY(S)	
			TO:	DATA SHEETS	DISPLAY(S)	
	MANUAL	TRANSFER DATA SHEETS TO TASK LEADER (D/I)	BY:			
			TO:			
		TRANSFER DATA SHEETS, DISPLAY(S) & CALCULATIONS TO PROGRAM DATA CLERK (D/I)	BY:	DATA SHEETS	DISPLAY(S)	CALCULATIONS
			TO:	DATA SHEETS	DISPLAY(S)	CALCULATIONS
TRANSFERENCE OF MATERIALS BETWEEN PROGRAM DATA CLERK AND TASK LEADER IS ACCOUNTED FOR IN PROGRAM DATA CLERK'S LOG BOOK						
REMARKS: (NOTE IF ATTACHMENTS)						

TI-23130A

SHEET 1–ACCOMPANY DATA SHEETS
SHEET 2–PROGRAM DATA CLERK LOG
SHEET 3–HELD AT PROCESSING POINT FOR RECORDS AFTER PROCESSING IS COMPLETE

Figure 133. TI form 23120A, general ecology data/ displays progress sheet.

entry errors and were transferred to the appropriate C-E Crest data sheets (Figures 134 to 137). TI field and laboratory data sheets were placed in locked program files as part of the permanent project documentation; C-E Crest data sheets were transferred with cover letter to the C-E Crest Program Manager who assumed all data processing responsibilities for the program. Copies of the C-E Crest data sheets were maintained in the TI program files as part of the permanent documentation.



CREST

SUBMITTED BY ______

PROGRAMMED BY ______

DATE ______

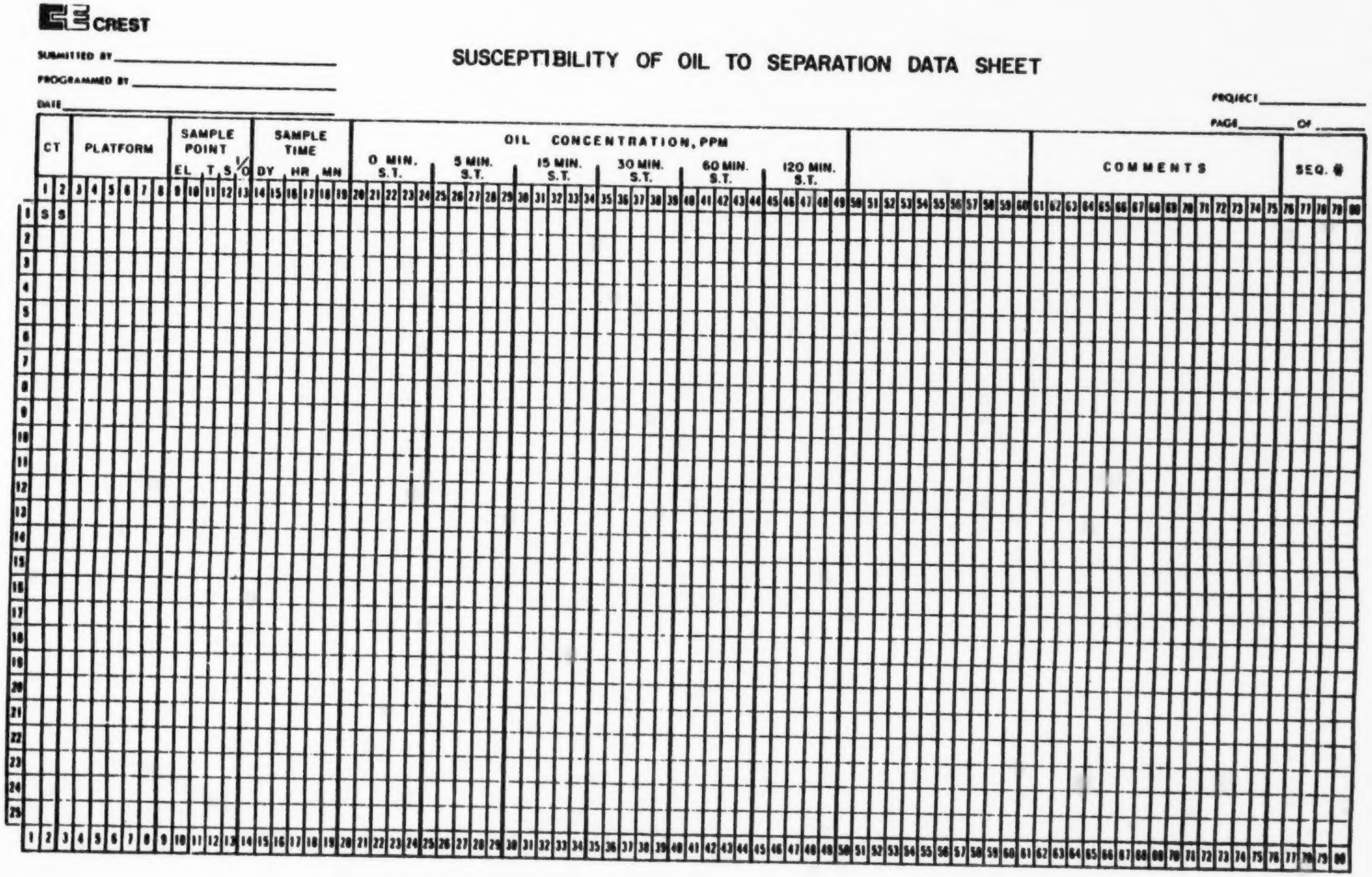
TI FIELD ANALYTICAL DATA SHEET

PROJECT ______

PAGE ____ OF ____

	CT	PLATFORM	SAMPLE POINT	SAMPLE TIME	IR/OIL PPM	TEMP °C	PH	S.G. OIL	S.G. WATER	WATER CUT %	SURFACE TENSION dynes/cm		IR SILICA PPM	IR FILTER PPM		SEQ. #
			EL T S I/O	DY HR MN							OIL	WATER				
	1 2	3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33	34 35 36 37 38	39 40 41 42 43	44 45 46 47 48	49 50 51 52 53	54 55 56 57 58	59 60 61 62 63	64 65 66 67 68	69 70 71 72 73 74 75	76 77 78 79 80
1	T F															
2							.	.	.	.						
3							.	.	.	.						
4							.	.	.	.						
5							.	.	.	.						
6							.	.	.	.						
7							.	.	.	.						
8							.	.	.	.						
9							.	.	.	.						
10							.	.	.	.						
11							.	.	.	.						
12							.	.	.	.						
13							.	.	.	.						
14							.	.	.	.						
15							.	.	.	.						
16							.	.	.	.						
17							.	.	.	.						
18							.	.	.	.						
19							.	.	.	.						
20							.	.	.	.						
21							.	.	.	.						
22							.	.	.	.						
23							.	.	.	.						
24							.	.	.	.						
25																
	1 2	3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33	34 35 36 37 38	39 40 41 42 43	44 45 46 47 48	49 50 51 52 53	54 55 56 57 58	59 60 61 62 63	64 65 66 67 68	69 70 71 72 73 74 75	76 77 78 79 80

Figure 134. C-E Crest, TI field analytical data sheet.



CREST

SUBMITTED BY ____________

PROGRAMMED BY ____________

DATE ____________

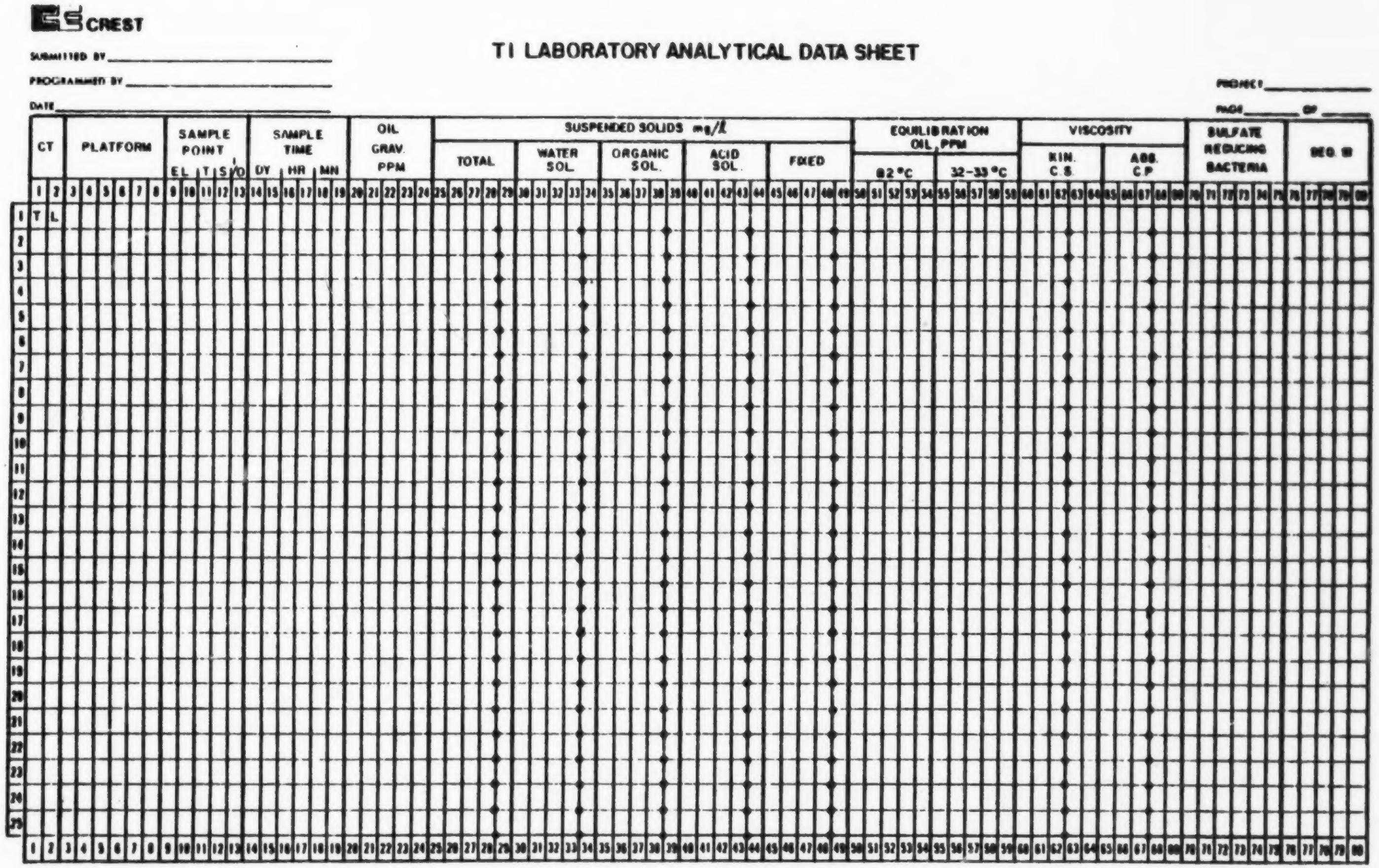
SUSCEPTIBILITY OF OIL TO SEPARATION DATA SHEET

PROJECT ____________

PAGE ______ OF ______

	CT	PLATFORM	SAMPLE POINT	SAMPLE TIME	OIL CONCENTRATION, PPM							COMMENTS	SEQ. #
			EL T S I/O	DY HR MN	0 MIN. S.T.	5 MIN. S.T.	15 MIN. S.T.	30 MIN. S.T.	60 MIN. S.T.	120 MIN. S.T.			
	1 2	3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33 34	35 36 37 38 39	40 41 42 43 44	45 46 47 48 49	50 51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70 71 72 73 74 75	76 77 78 79 80
1	S S												
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
	1 2	3 4 5 6 7 8 9	10 11 12 13 14	15 16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31 32 33 34 35	36 37 38 39 40	41 42 43 44 45	46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61	62 63 64 65 66 67 68 69 70 71 72 73 74 75 76	77 78 79 80

Figure 135. C-E Crest, susceptibility of oil to separation data sheet.



CREST

SUBMITTED BY ____________

PROGRAMMED BY ____________

DATE ____________

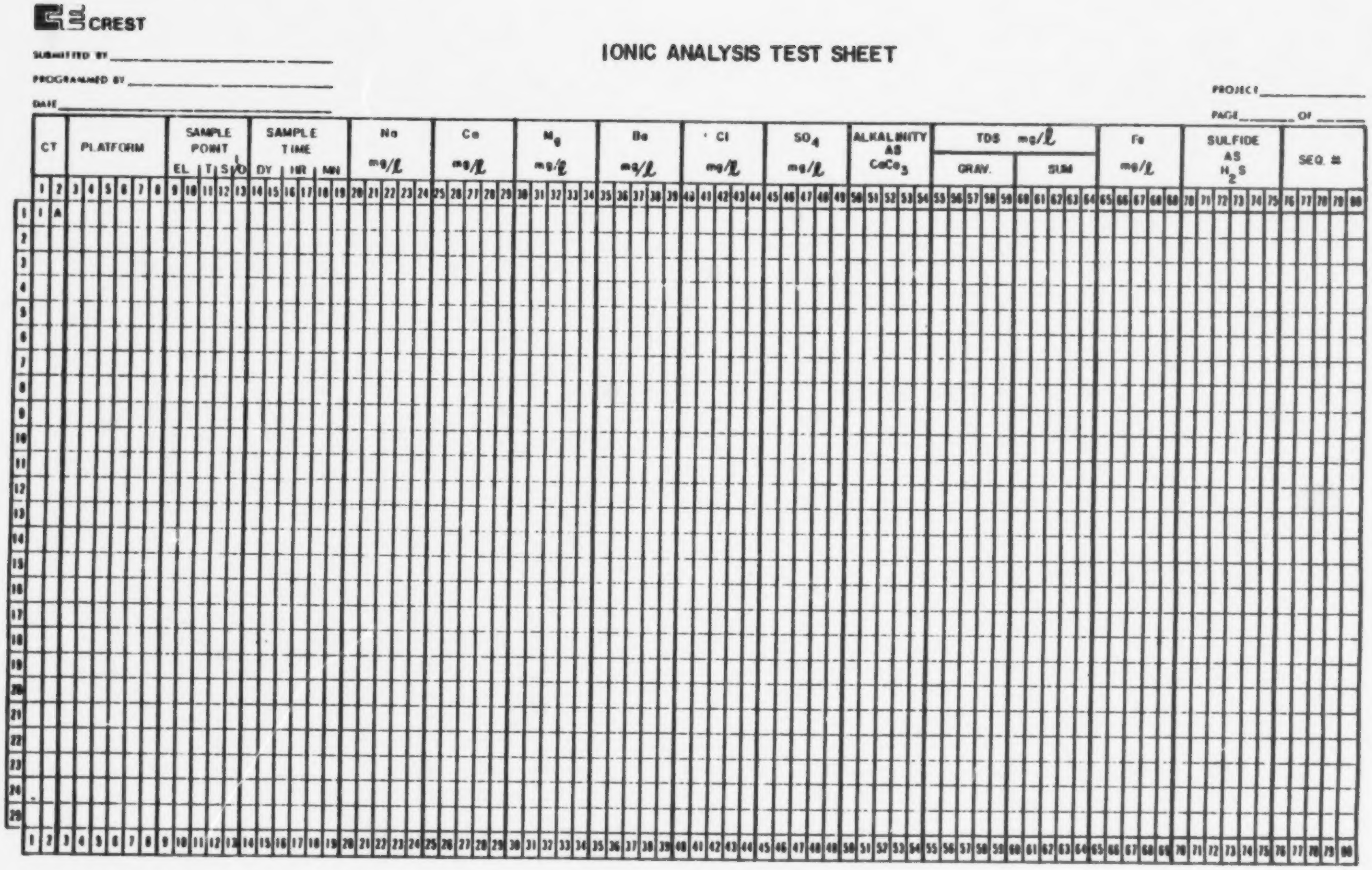
TI LABORATORY ANALYTICAL DATA SHEET

PROJECT ____________

PAGE ______ OF ______

	CT	PLATFORM	SAMPLE POINT			SAMPLE TIME			OIL GRAV. PPM	SUSPENDED SOLIDS mg/ℓ					EQUILIBRATION OIL, PPM		VISCOSITY		SULFATE REDUCING BACTERIA	SEQ. ID
			EL	T	S/D	DY	HR	MN		TOTAL	WATER SOL.	ORGANIC SOL.	ACID SOL.	FIXED	82 °C	32–33 °C	KIN. C.S.	ABS. C.P		
	1 2	3 4 5 6 7 8	9 10	11	12 13	14 15	16 17	18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33 34	35 36 37 38 39	40 41 42 43 44	45 46 47 48 49	50 51 52 53 54	55 56 57 58 59	60 61 62 63 64	65 66 67 68 69	70 71 72 73 74 75	76 77 78 79 80
1	T L																			
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				
21																				
22																				
23																				
24																				
25																				
	1 2	3 4 5 6 7 8	9 10	11	12 13	14 15	16 17	18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33 34	35 36 37 38 39	40 41 42 43 44	45 46 47 48 49	50 51 52 53 54	55 56 57 58 59	60 61 62 63 64	65 66 67 68 69	70 71 72 73 74 75	76 77 78 79 80

Figure 136. C-E Crest, TI laboratory analytical data sheet.



CREST

SUBMITTED BY

PROGRAMMED BY

DATE

IONIC ANALYSIS TEST SHEET

PROJECT

PAGE ___ OF ___

	CT	PLATFORM	SAMPLE POINT EL | T | S | D	SAMPLE TIME DY | HR | MN	Na mg/ℓ	Ca mg/ℓ	Mg mg/ℓ	Ba mg/ℓ	Cl mg/ℓ	SO_4 mg/ℓ	ALKALINITY AS $CaCO_3$	TDS mg/ℓ GRAV.	TDS mg/ℓ SUM	Fe mg/ℓ	SULFIDE AS H_2S	SEQ. #
	1 2	3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33 34	35 36 37 38 39	40 41 42 43 44	45 46 47 48 49	50 51 52 53 54	55 56 57 58 59	60 61 62 63 64	65 66 67 68 69	70 71 72 73 74 75	76 77 78 79 80
1	1 A															
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
	1 2	3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18 19	20 21 22 23 24	25 26 27 28 29	30 31 32 33 34	35 36 37 38 39	40 41 42 43 44	45 46 47 48 49	50 51 52 53 54	55 56 57 58 59	60 61 62 63 64	65 66 67 68 69	70 71 72 73 74 75	76 77 78 79 80

Figure 137. C-E Crest, ionic analysis test sheet.

GLOSSARY

API gravity: The measure of the gravity of liquid petroleum products derived from specific gravity in accordance with the following equation:

$$\text{API gravity} = \frac{141.5}{\text{specific gravity}} - 131.5$$

choke: A type of orifice installed in a line at the wellhead to restrict the flow and control the rate of production of oil or gas.

corrugated plate interceptor: A gravity separator in which the fluid flows between corrugated parallel plates. Oil must rise only short distances by gravity to contact the plates.

dispersed oil: As defined for this report, the non-polar material extracted from brine by Freon and not adsorbed by silica gel from the Freon as part of the IR-Oil w/Silica Gel test.

flotation, dispersed gas: A process for separating oil from water in which mechanically or hydraulically dispersed gas bubbles adhere to oil droplets and rise rapidly for separation by skimming.

flotation, dissolved gas: A process for separating oil from water in which gas bubbles formed when pressure is reduced on a gas-saturated solution adhere to oil droplets and rise to the surface for oil removal by skimming.

flowing tubing pressure: The pressure in the tubing at the wellhead of a flowing well.

flowing well: A well that produces oil or gas by its own reservoir pressure. A well that does not employ pumps or other artificial lifting means.

free water knock out: A vertical or horizontal vessel into which oil or emulsion is run to allow water that is not emulsified with the oil to drop out.

gas lift: The process of raising fluid from a well by means of gas injected down the well through tubing or through the tubing casing annulus. Injected gas reduces the weight of the fluid so that the formation pressure forces the fluid out of the wellbore.

EPA-287 (Cin.)
(4-76)

GLOSSARY (continued)

gas-oil ratio (GOR): A measure of the volume of gas produced with oil; expressed in cubic feet per barrel or cubic meters per metric ton.

gravity separator: A vessel in which oil and water are separated by settling as the result of specific gravity differences. In this report, it refers primarily to the gravity separation step used specifically to remove oil from brine in preparation for flotation.

gun barrel: A settling tank used in separating oil and water in the field. In this report, all gun barrels had round inlet pipes extending downward in the center of the tank and operated at atmospheric pressure.

heater treater: A vessel in which oil, water, and emulsions are placed to remove water and gas, and render oil of acceptable quality to a pipeline. Heater treaters are a combination of a heater, a free water knock out, and an oil and gas separator.

hydraulic loading: Hydraulic loading is the volumetric flow through a treating vessel. In this report, stated in terms of flow rate, percent of design flow rate, and overflow rate.

overflow rate: The surface area divided by the flow rate through a gravity separator or treating vessel.

shut in bottom hole pressure: The pressure existing at the bottom of a well when the surface valves are closed.

skim tanks: Gravity oil/water separation tanks with various shapes and flow patterns. In this report, all skim tanks operated at atmospheric pressure with a controlled surface level.

soluble oil: As defined for this report, the polar materials that are extracted from brine by Freon and then are adsorbed by silica gel from the Freon as part of the IR-Oil w/Silica Gel test.

test separator: An oil and gas separator employed to separate relatively small quantities of oil and gas which are diverted through the testing device on a lease.

three-phase separator: A separator employed to separate oil, gas, and water by gas/liquid phase separation and oil/water specific gravity difference.

two-phase separator: A separator employed to separate oil and water from gas.

treatability: As defined for this report, the lowest oil content to which a brine could be treated by physical processes as indicated by the IR-Oil w/Silica Gel test.

GLOSSARY (continued)

water cut: The proportion of water in produced fluids. In this report, stated in percent as determined by ASTM Method D1796-68 (1973).

wellhead: The equipment used to maintain surface control of a well.